NUTRITION

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PART I

GENERAL FOOD REQUIREMENTS

INTRODUCTION TO PART I

Food selection has engaged the attention of man ever since the first pangs of hunger created the demand for food. Man's earliest food experiments were probably matters of selection or rejection on the basis of taste and satisfactory consequences. We have progressed a long way since these early experiments, but it is only during the last half century or perhaps in a lesser period that food selection has assumed the aspect of a science. In fact we might say with little fear of contradiction that mankind has learned more about food selection and the part played by food in the control of health during the past twenty-five years than in any other period of the world's history.

There are certain studies which may be left to inclination and aptitude. There are other studies whose pursuit may be safely omitted from our personal attention because when we need their benefits we can hire experts to supply them. But all of us eat. All of us either are kept well or become ill in proportion as our food selection is sound or faulty. All of us eat several times a day and on that account alone, few can afford to hire

experts to select food for them. Combine with these obvious facts the realization that likes and dislikes are no longer criteria for sound food selection and it becomes worth while for all of us to devote a little time to the learning of how to buy food, what to buy, and what to eat.

Where can we get such knowledge? The food manufacturer is primarily concerned in the sale of his products. His advertisements may tell the truth about his own product but the advice of individual manufacturers is certainly not unbiased and hardly a substitute for scientific advice. Many of the present data are too recent to be found in text-books. Furthermore such texts as have attempted to present the data, with few exceptions, assume a training and experience in nutrition and food chemistry that makes their presentation unintelligible to the layman.

All of these reasons have made it seem worth while to try to present in simple language some of the fundamental principles which nutrition experts have found necessary to follow in selecting proper food for man. Also, since the facts necessary to perfect food selection are still incomplete, to outline the type of experiments that are being made, and the problems that are considered un-

solved or needing further study, so that we will realize why the expert often cannot answer our questions.

We suffer quite as much today from the dogmatic statements of food faddists as from lack of scientific data. No scientist of today will contend that anyone has found the optimum diet for any class of people. It is still true that one man's meat may be another man's poison. If, however, we have no means of determining whether the advisor is intelligent or biased, or no facts to use as test stones, our credulity may lead us into opinions that are not only without foundation but dangerous to health and happiness.

It will be attempted, therefore, to separate fact and theory and to avoid dogmatism. We shall try to answer:

1. What are the proved values contributed by specific types of foods?

2. How can we measure foods to determine what values they have?

3. How can we tell how much to eat?

4. What are the kinds of troubles that will appear if certain types of foods are omitted?

We shall also try to outline some of the modern problems in nutrition and the manner in which

they are being studied for, unlike Latin grammar, the rules which govern proper food selection are in state of development making necessary constant revision in practice.

CHAPTER I

When Is a Food A Complete Food?

The briefest answer to the question of when is a food a complete food is that a food is complete when we may make it our sole diet and yet meet every need of the body. There are very few such foods. In infancy milk almost fits the definition and there have been experiments in recent years to manufacture such complete articles of diet. During the late war such experiments took the form of an emergency ration which a soldier might easily carry and which would enable him to survive if cut off from his regular food supply. Still more recently a baker in one of our eastern cities produced a loaf of bread so supplemented that it constituted a complete diet in itself. Such experiments ordinarily arouse little interest for we instinctively prefer variety in our diet. Single foods are monotonous and fail to produce the pleasure that accompanies the eating of a meal composed of a variety of foodstuffs. Nature seems to have recognized this fact, for few of our common foodstuffs are "complete" and many are duplicates in values.

The first point to be stressed then is that while we should make our diet complete in all nutritional factors, we shall have to accomplish this by combining foods that are in themselves incomplete. We must know what factors are available in the different foods and what combinations make the sum-total adequacy. What are the factors that are distributed in foods? The nutritional factors that are necessary to make a diet complete or adequate are:

1. Energy value usually measured in calories or heat units.

2. Nutrient value, amount and kind, usually measured in terms of weight.

3. Nutrient quality.

4. Vitamins, quantity not yet accurately measurable in weight units as in the case of nutrients, but expressible by comparing richness and poorness.

5. Digestibility, measured by experimental tests which enable us to determine whether the article tested will yield its values to the human body.

6. Palatability, measured by its effect upon the taste of the individual and while not absolutely essential to completeness as in the case of factors 1 to 5 still a desirable factor and one essential to happiness in food consumption.

The brevity of this list suggests that it will not be an impossible task to learn how to measure food values. The values need further definition, however, for as it now is we have a series of names or symbols with but little idea of what they mean.

ENERGY VALUE

When we buy coal to heat a furnace we become incensed if the dealer sells us an article that is largely stone. We all know that coal burns and stone does not. We also know that when coal burns it generates heat and that with the heat produced we can expand steam and heat a home or run an engine. In other words, we convert coal, by burning, into a source of "doing things" or *energy*. The human body also does things and hence it also must have a source of energy. Food is that source and to convert food into energy we burn it in the body. When we first recognized that food is human fuel we naturally sought a means of measuring the relative fuel value of different foods. A method had already been devised for measuring the value of different coals and this method was simply extended to foods. By suitable apparatus we can measure accurately the amount of coal or food necessary to raise the

TABLE 1

The energy values of some common foodstuffs in calories

FOODSTUFF	CALORIES IN 1 POUND	FOODSTUFF	CALORIES IN 1 POUND
Meats:		*Dairy products:*	
Pork chops	1,530	Milk	314
Sirloin steak	1,099	Cheese (American)	1,990
Leg of lamb	876	Eggs	672
Chicken	493	Butter	3,491
Bacon	2,840		
		Root vegetables:	
Cereals:		Potatoes (white)	378
White flour	1,623	Carrots	204
Corn meal	1,620	Beets	209
White bread (average)	1,182	Turnips	178
		Green vegetables:	
Dried seeds:		String beans	184
Bean's navy	1,565	Chard	173
Beans Lima	1,586	Cabbage	143
Peas	1,611	Spinach	109
		Asparagus	100
Fish:		Celery	84
Mackerel	629	Cucumbers	79
Salmon	582		
Blue fish	402	*Fruits:*	
Flounder	282	Bananas	447
Cod	209	Apples	285
Oysters	228	Oranges	233
		Grape fruit	235

temperature of a given volume of water one degree in temperature. We had to have a name for this amount and adopted the French word that means heat, viz., "calorie." With such apparatus then, we can measure the calories producible by a given weight of any substance that will burn; wood, coal, hay, bread, butter, etc. Thus it is logical to express the amount of energy producible by burning a given quantity of food in the body by determining the number of calories a pound or ounce of that food will yield. Table 1 illustrates the comparative energy values of some common foodstuffs. A study of this table will show that dried seeds, cereals and meats are our richest sources of energy; that fruits and green vegetables are also sources of energy but not in so concentrated a form. Also that the more fat a food contains the higher its fuel value and the more water present the less its energy content.

NUTRIENTS

Analyses of the human body show that it consists largely of water, contains a fairly large amount of organic compounds composed mainly of the chemical elements carbon, hydrogen, oxygen, nitro-

gen, sulfur and phosphorus, and a smaller amount of inorganic compounds among which are represented the elements calcium, sodium, iodine, chlorine, iron, etc. To grow or even to maintain weight, we must renew these constituents continuously. This we do by the consumption of foods of animal, vegetable, and mineral origin. It would be difficult to list all of these foods. Fortunately, regardless of their origin, there are certain groups into which the components of the various foods fall, groups with common chemical and physiological properties. These groups are called for brevity, *nutrients*. Science recognizes five such groups or nutrients. They have been given the following names: Proteins, lipins, carbohydrates, mineral salts, and water. The first three are called *organic* nutrients because they are substances in which carbon is the predominant element.

Proteins. Meats, cheese, milk, fish, and certain vegetables and nuts such as peas and peanuts are particularly rich in the nutrient called protein, which always contains the element nitrogen. What the biologist terms protoplasm, or the living matter of all plant and animal cells, is largely composed of this nutrient protein. When the

layman speaks of "meats and meat substitutes" he is referring to foods that will supply this nutrient protein and no living animal can survive unless it receives a regular supply of this nutrient in its food.

Lipins. These nutrients are also organic but do not contain nitrogen, being composed mainly of carbon, hydrogen, and oxygen. Fats are the principal examples of this group but in recent years it has been learned that foods contain and the body requires certain compounds which, like the fats, are soluble only in ether and chloroform or alcohol but which, unlike true fats, will not make soaps. The substance that makes gall stones (cholesterol) is such a lipin. The term lipin then is broader than the term fat and includes fats and fat-like compounds. Formerly it was taught that these substances in the food were merely sources of energy, but we know now that like the proteins they are necessary to replace body tissue losses as well as to supply energy.

Carbohydrates or glucides. The common terms for these nutrients are sugars and starches. Like lipins they contain only the elements carbon, hydrogen and oxygen and are used mainly as sources of energy but like the two nutrients just

mentioned are not solely energy foods, for parts of our body are made out of these nutrients. The most common name for these nutrients is carbohydrate but recently the International Chemical Union has suggested a shorter term, viz., glucide. This name may come into general use for several reasons but as yet has not become of wide use in America.

TABLE 2

Nutrient content of some common foodstuffs

FOOD STUFF	PROTEIN	CARBOHYDRATE	LIPIN	MINERALS	WATER
	per cent	*per cent*	*per cent*	*per cent*	*per cent*
Beef sirloin	19.0	00.0	19.1	1.0	61.3
White flour	13.3	72.7	1.5	0.6	11.9
Potatoes (white)	2.2	18.4	0.1	1.0	78.3
Apples	0.4	14.2	0.5	0.3	84.6

Mineral salts. Bones contain lime, blood contains iron, and even copper and zinc are found in certain parts of our body. Hence we cannot get along on organic nutrients alone. Substances which supply these inorganic elements are called mineral nutrients. Ordinary table salt is an example of this group.

It is obvious that since we must renew our chemical constitution continuously, a complete diet

must not only contain all these nutrients but the amounts supplied must be computed according to the needs of the individual. We must know not only how much energy a pound of food will supply, but the amounts and kinds of nutrients it contains. Such information has been tabulated for our use and table 2 is a typical method of expressing such information. With like tables[1] it is evident that if we know the weight of a given foodstuff we can easily calculate the weight of nutrients that a given amount will contribute to the daily diet. These tables also enable us to classify foods into protein suppliers, fat sources, etc.

NUTRIENT QUALITY

Nutrients of a given kind have similar chemical properties, and it formerly was believed that there was no difference whether we obtained our protein or carbohydrate or lipin from meat, or vegetables, or seeds, provided the supply was ample. As the study of physiology progressed, however, we found

[1] Such tables will be found in many texts on food chemistry. The most complete tables are the Atwater and Bryant Tables published by the United States Department of Agriculture as Bulletin No. 28 (Revised Edition). The table is taken from this Bulletin.

that nutrients might differ from one another in physiological properties. De Vaux, for example, tried to prove to the besieged population of Paris that gelatin was just as good a protein as milk casein or meat protein, but the experiment demonstrated that he was sadly mistaken. We still hear controversy over whether corn sugar is the physiological equivalent of cane sugar or starch. We know today that the protein of white flour lacks something necessary to growth and that bean and pea proteins are not as valuable to the human body as egg, meat or milk proteins. Nutrients of similar type then, may differ in what they will do for us. We know that there are many different kinds of motors and that while all are motors they do not all do the same kind of work. So with nutrients. We must not only select the right amounts and kinds of nutrients in our purchase of foods but we must be sure that the *quality* of these nutrients is such as to make them supply all the needs of our body.

VITAMINS

An internal combustion engine runs on gasoline. The gasoline is the engine's "food" and source of energy. If we do not provide an electric spark,

however, the gasoline will not explode. The spark is not food or fuel but it makes the fuel available. Since 1906 we have learned that the human body resembles the gasoline motor, in that it uses nutrients as food-fuel, but if the foods lack certain minute amounts of special chemical compounds they fail to function properly in the body. The existence of these substances can be demonstrated by various experimental methods. No one has ever isolated the principal ones but we have learned to apply tests that will tell us whether they are present or not, and whether the supply is adequate or inadequate in a given kind of foodstuff. These substances are called vitamins, and the different kinds are briefly designated by letters, e.g., vitamin A, vitamin B, vitamin C, etc.

The minuteness of the quantities that are significant is difficult to visualize. J. C. Drummond of England has shown by the use of a concentrated preparation of vitamin A that a white rat, consuming one-half ounce of food daily, can be kept in health or killed by adding or subtracting from its diet $\frac{1}{3,000,000}$ ounce of this concentrated vitamin. Since Drummond's concentrate is not pure vitamin, the actual amount required by the rat is less

than $\frac{1}{6,000,000}$ of its daily food intake. It is thus seen that a foodstuff must not only supply the factors of energy value, nutrient value, and nutrient quality, but it also must provide vitamins.

DIGESTIBILITY

The human body is built around a tube (the digestive tract or alimentary canal). When we swallow food we have simply introduced it into one end of the tube. To be of actual use in building more body, or in releasing energy, food must pass through the wall of this tube into our blood and thence to the parts of the body where it is needed. Beefsteak and potatoes will not do this. They first must undergo certain chemical changes. These chemical changes are spoken of collectively as digestion. A foodstuff may meet all the requirements previously described and yet not be able to get out of the tube. Hay, for example, is a real foodstuff which has such properties. A horse or cow can digest it but man cannot.

Our foodstuffs must be capable of changes within our tubes into forms which will not only pass into the blood but which the blood can carry

to all parts of our bodies. That is what we mean by digestibility in the chemical sense.

Some foods which we eat are much more quickly changed than others. If the change is not rapid enough it may travel clear through the digestive tract without being completely changed and the unchanged part will be lost in the feces. Hence the term indigestible is sometimes used to indicate that while a foodstuff is chemically digestible, it may fail of digestion if eaten in too great a quantity, or in combination with too many other foods. A diet then to be strictly digestible must not only be chemically digestible but so blended that the process functions normally and no food is lost.

The movement of foods through the digestive tube is accomplished by muscles and if these muscles get flabby, lose tone we say, the progress of the food is delayed. It has been found that a mild friction stimulates these muscles, and for this reason it is recommended that our foods include a certain amount of matter which is of no nutrient or energy value, but which does, because of its bulk and the friction it creates, keep the muscles of the digestive tract in good condition, thus reducing constipation and its attendant ills.

The bran of whole meals and the connective tissue of meats function in this way and those who neglect this factor in the diet are apt to suffer. Fruits, green vegetables, and nuts are all good sources of roughage.

PALATABILITY

It has been demonstrated that even if a food does not taste good it is not necessarily valueless to the body. It has also been demonstrated that appetite and taste are unreliable guides to correct eating. In general, however, it is desirable that food combinations taste good, for our digestive apparatus works best when we are in a happy frame of mind. Palatability is desirable in food combinations though not absolutely essential. We must not permit our prejudices to keep us from tasting certain good foods because we think they will not taste good or because they are strange to us. Let us learn to like what is good for us, let us make this a part of the training of children, and if there are several ways in which a given food can be prepared let us select the most palatable form.

With these explanations as to what constitutes food values let us conclude this chapter by com-

paring the two foodstuffs shown in table 3, and thus illustrate the manner in which foodstuffs can be judged for completeness or incompleteness and their relative values determined.

TABLE 3

Comparative analysis of two common foodstuffs in nutritional factors

TEST FACTORS	MILK	REMARKS	WHITE FLOUR	REMARKS
Energy value	1 ounce gives 20 calories and 1 quart weighs 34.4 ounces.	A fair source of energy but not a rich source	1 ounce gives 100 calories	A concentrated source of energy and cheap.
Nutrients kinds and amounts	1 ounce contains: 0.87 ounce water 0.33 ounce protein 0.04 ounce lipins 0.05 ounce carbohydrate. 0.007 ounce minerals. Minerals rich in calcium.	Valuable source of all nutrients. An especially good source of fat. Best known source of calcium.	1 ounce contains: 0.13 ounce water 0.11 ounce protein 0.01 ounce lipin 0.75 ounce carbohydrate. 0.005 ounce minerals. Minerals much richer in phosphorus than in calcium.	High carbohydrate content makes it a very valuable energy food. Very little fat. The predominance of phosphorus in minerals makes it less valuable than milk ash.

Nutrient quality	Proteins, fat, carbohydrate and ash of exceptionally high physiological quality.		Carbohydrate of good quality. Protein of poor quality, alone will not permit growth. Fat practically lacking. Minerals too high in acid radicals. Not a bad food but must be supplemented with other nutrients of good quality.	
Roughage	None		Practically none.	
Vitamins	Contains A and B. in abundance. Contains some C. Contains little D. Contains E.	Should not be relied upon as a source of C or D.	Contains little of any vitamine.	Must not be relied upon as a source of any vitamins.
Digestibility	Complete and rapid.		Complete and rapid.	
Palatability	Good		Good when properly cooked.	

Summary: Milk is an almost complete food judged by the above criteria, provided we can eat enough to meet our calorie needs. This is easy in infancy but an adult would require at least 1 gallon a day. It is lacking in the iron necessary to protect against anemia. Experience has shown that to keep infants from scurvy and rickets it should be supplemented with rich sources of these vitamins such as orange juice and cod-liver oil.

White flour is a good energy food and cheap. By adding butter we can remedy its lack of vitamin A and fat. Meats, eggs or milk would supplement its poor protein. Milk in particular would remedy its lack of calcium, but not its lack of iron. It is a wholesome, digestible, source of energy but incomplete in many factors and must not be made the sole source of diet.

CHAPTER II

The Energy Requirement

The principal factors that must be supplied by the diet have been briefly outlined in Chapter I. Sufficient definition was given to indicate just what factors we may expect to find in foods, but certainly not enough to enable us to measure food values or to determine our need of these factors. Such ability demands a more detailed consideration of each factor, and in this chapter attention will be given to the energy requirement.

How many calories do we need a day and where can we get them? The correct answer to this question marks the first successful step in the selection of the daily diet. At present the methods of determining where to get our calories are more available (see page 46) than is knowledge of individual needs. The latter vary with each individual and the very methods of measuring human calorie needs are still in process of development. Let us consider the human need problem first.

Lavoiser was the first to show that the air we

inhale supplies a certain gas (oxygen) which combines in the body with carbon compounds and is exhaled as carbon dioxide gas. He showed that to exclude oxygen from the human lungs is as effective in stopping human machinery as is the exclusion of food. These observations were our first clues to the principle that our power to operate muscles and organs and to maintain body temperature was derived by oxidizing the food we eat in our tissues, and that our daily output of carbon dioxide gas and intake of oxygen are measures of that combustion.

It also has been learned that if for any reason our food is inadequate in calories the fire does not immediately go out but that our tissues continue to operate for some time at the expense of stored nutrients, and as a result we rapidly lose weight. This latter fact is the scientific basis for all weight-reducing schemes that attain their end by lessening food consumption. Such schemes make us "count the calories." If our daily diet contains less calories than we need, the body burns up its own stores to meet the deficit. If we eat our exact requirement, we tend to remain at constant weight. If we eat more than our requirement, we either eliminate the excess in our excreta or store

TABLE 4

Average height weight data compiled by the Life Extension Institute

(Weights include shoes and ordinary indoor clothing)

AGE	HEIGHTS IN FEET AND INCHES						
	5 ft. 0 in.	5 ft. 2 in.	5 ft. 4 in.	5 ft. 6 in.	5 ft. 8 in.	5 ft. 10 in.	6 ft. 0 in.
I. Males							
years							
15	107	112	118	126	134	142	152
20	117	122	128	136	144	152	161
25	122	126	133	141	149	157	167
30	126	130	136	144	152	161	172
35	128	132	138	146	155	165	176
40	131	135	141	149	158	168	180
45	133	137	143	151	160	170	182
50	134	138	144	152	161	171	183

II. Females

	4 ft. 8 in.	4 ft. 10 in.	5 ft. 0 in.	5 ft. 2 in.	5 ft. 4 in.	5 ft. 6 in.	5 ft. 8 in.	5 ft. 10 in.
15	101	105	107	112	118	126	134	142
20	106	110	114	119	125	132	140	147
25	109	113	117	121	128	135	143	151
30	112	116	120	124	131	138	146	154
35	115	119	123	127	134	142	150	157
40	119	123	127	132	138	146	154	161
45	122	126	130	135	141	149	157	164
50	125	129	133	138	144	152	161	169

it and gain weight. There is then a direct relation between calorie intake and body weight. A very imperfect basis for estimating the calorie adequacy of the diet is by use of the scales.

Extensive statistical studies have been made to determine the weight that is compatible with health in normal Americans of a given height and age. Table 4 shows excerpts from such a compilation by the Life Extension Institute. Let us assume that you have been examined by your family physician and pronounced in good health. Let us also assume that you are a male about forty-five years old, 5 feet, 10 inches tall and weigh 170 pounds. If from day to day your weight remains about the same you can assume with some certainty that you are buying and eating enough calories and need not make any more careful measurement of the purchased food on that account. If you begin to gain or lose the change may very probably be due to eating too many or too few calories, and if correction of this restores you to normal you can be reasonably certain of this as the cause. The daily weight may, therefore, serve as a crude index of the adequacy of the diet in calories.

It will be evident, however, to anyone who has

made observation of his fellows that many people are healthy and yet under the average weight value; heredity being now a recognized factor in determining size. Also that many people eat enormously and still remain thin, while others wax large on small intakes of food. In brief, weight alone is not a complete index of the adequacy of a diet as to calories. For this reason parents may avoid much needless anxiety if they will realize that their child's failure to come up to average weight is not necessarily due to their error in feeding or to something seriously wrong in the child. If a child's under-weight or over-weight is due to lack or excess of food it is a matter easily tested and remedied. If the changes in intake do not make the child assume the statistical figure, the child is not necessarily abnormal or diseased.

The measurement of calorie needs is then not entirely determinable by the scale weight of the consumer. Is there a better means of estimating requirement?

INDIRECT METHOD FOR MEASURING CALORIE NEEDS

The indirect method was first employed systematically by Voit, a German physiologist, and his

method was extended to American types by Atwater and Langworthy. During the world war a similar method was devised and used extensively in the training camps of the United States Army under the direction of Dr. John R. Murlin. A description of this method and some of its results will explain how it was learned that an American soldier may keep in good fighting trim on about 3600 calories per day.

A company unit was selected for a test. The men, all healthy, were kept under observation for a week. At the beginning of the week an inventory was made of all the food stores on the company shelves and an accurate record kept of all purchases during the week. At the end of the week a final inventory was made. The latter subtracted from the first inventory and purchases gave a record of the kinds and amounts of foods offered for consumption during that period. Obviously not all of the food was eaten.

To determine the actual consumption, two corrections were applied. Analytical tables, furnished by the United States Department of Agriculture, supplied the calorie value of the edible portion of the various foodstuffs. From these tables was calculated the edible portion of the

TABLE 5

Per capita consumption of food in army camps (1917–1918)

A. Results of the study of 427 company messes (averages); about 250 men to each mess

	PROTEIN	FAT (LIPINS)	CARBO-HYDRATE	CALORIES
	ounces	*ounces*	*ounces*	
Supplied in diet	4.62	4.73	18.20	3,899
Wasted	0.31	0.39	1.09	266
Consumed per man per day	4.31	4.34	17.11	3,633

Costs:

Food consumed in 1917 and 18	$0.4406
Food wasted	0.0320
Total cost of ration per man per day	0.4726

B. Nutrients and calories consumed per man per day by troops under different conditions

TYPE OF TROOPS	NUMBER OF MESSES STUDIED	PRO-TEIN	FAT	CARBO-HYDRATE	CALORIES
		ounces	*ounces*	*ounces*	
Line troops in active training and in spruce construction camps	263	4.48	4.24	17.05	3,615
Medical troops including patient meals	20	3.99	4.37	15.35	3,405
Recruits usually just inoculated	36	4.13	3.85	15.35	3,275

food actually put upon the mess plates. To secure the second correction it was necessary to measure the edible waste. This was obtained by collecting the edible waste left by the men on their plates, mixing the collection for a day, grinding it to a uniform paste, and weighing it. Samples were taken and analyzed and converted by proper mathematical computations into the amounts actually wasted per man per day. Table 5 shows how such data were utilized.[1] This method does not indicate whether the consumption was more than that necessary for health. However, since a large number of companies in different sections of the country were averaged, the results gave a fairly satisfactory idea of the food consumed by men in good health when left to their own selection and tastes. A safe minimum was secured on which to base ration allowances and control costs and waste.

A "statistical" method, such as shown in table 5, applied to groups of workers of varying ages, sex and occupation supplies much of our information today. By such studies, with variations in the groups and foodstuffs used, much valuable

[1] J. R. Murlin and C. W. Miller, *American Journal of Public Health*, June, 1919, vol. ix, p. 401.

data has been obtained. On these studies Voit suggested the following allowances as adequate for an adult man of 170 pounds weight and at moderate muscular work:

Protein	118 grams or 4.16 ounces[2]
Fat	56 grams or 1.98 ounces
Carbohydrates	500 grams or 17.62 ounces
Calories	2986

Langworthy compiled data from various sources in America and reported the following:

	Proteins	*Calories*
Man at very hard work	177 grams or 6.26 ounces	6000
Farmers, mechanics, etc.	100 grams or 3.60 ounces	3425
Business men and students	106 grams or 3.74 ounces	3285
Inmates of institutions with very little activity	86 grams or 3.06 ounces	2600
Very poor people usually out of work	69 grams or 2.43 ounces	2100

The studies of Voit and Langworthy thus show that in practice the greater the activity the more

[2] It is customary in scientific texts to express units of measurements in the metric system. The use of the gram is more convenient in a text such as this, but for the reader's assistance it will be noted here that grams and ounces may be evaluated as follows: 1 ounce equals 28.35 grams; 1 gram equals 0.035 ounces.

the need and consumption of calories; the fuel bill increases with the extent of the use of the engine. These studies serve a practical purpose but they are not quantitative measurements of human requirements, they merely measure human customs. Is direct measurement of requirement possible?

THE RESPIRATORY CALORIMETER

Since food is oxidized, or consumed, in the body to produce energy, it will be clear that the amount of oxygen consumed and the amount of carbon dioxide eliminated in a given period, if measurable, may serve to indicate both the fuel value of foods and the calorie consumption of the body. Zuntz devised an apparatus to accomplish this measurement. It consists of a gas mask fitting air-tight over mouth and nose, connected by pipes and valves to an apparatus for measuring and analyzing both the inspired and expired air. With it can be measured both the oxygen inhaled and the carbon dioxide exhaled in a given period. With such data available, it is possible to determine how many calories are represented by a given volume of inhaled oxygen. To obtain this datum requires another bit of information. The amount

of calories produced with a given quantity of oxygen may be determined in part, at least, by the kind of food we eat. To burn fat in the body or stove requires a larger supply of oxygen per ounce of fat than to burn an ounce of sugar or starch. Why this is so will be clear from a consideration of the chemical composition of these substances. Let us consider the digestion product of sugar and starches which actually reaches the tissues. We call this substance glucose and its chemical formula is $C_6H_{12}O_6$, showing it to be composed of 6 parts of carbon, 12 parts of hydrogen, and 6 parts of oxygen. How large a volume of oxygen must we use to completely convert this into carbon dioxide and water? The following chemical equation gives the answer:

Glucose	plus	Oxygen	gives	Carbon dioxide	plus	Water
$C_6H_{12}O_6$	$+$	$6O_2$	$=$	$6CO_2$	$+$	$6H_2O$

In other words, to completely burn a given amount of glucose to CO_2 and water, it will take 6 volumes of oxygen gas for every 6 volumes of CO_2 produced. The ratio of the CO_2 volume to the O_2 volume used in burning food stuffs is called the *respiratory quotient.* When an individual is burning only glucose in the body the respiratory quotient must

always be unity, because the respiratory quotient = CO_2/O_2 and in the case of glucose this value is 6/6 or 1. When fat is burned the respiratory quotient will be less than 1. Stearic acid is a typical digestion product of ingested fat in our body.

Stearic acid	plus	Oxygen	gives	Carbon dioxide	plus	Water
$C_{18}H_{36}O_2$	+	*26*O_2	=	*18*CO_2	+	$18H_2O$

R.Q. = CO_2/O_2 or 18/26 = 0.7 or less than 1

TABLE 6

Calorie production per liter of consumed oxygen when respiratory quotient is known

(After Zuntz and Schumberg)

RESPIRATORY QUOTIENT	CALORIES PER LITER OF CONSUMED OXYGEN
0.70	4.686
0.75	4.739
0.8	4.801
0.85	4.863
0.90	4.924
0.95	4.985
1.00	5.047

In other words, to burn 1 ounce of fat we need 8 more volumes of oxygen than we produce of CO_2.

Zuntz and Schumberg worked out a table of values by means of which they could convert the measures of inhaled oxygen into calorie produc-

tion if the respiratory quotient was known. Table 6 illustrates its use. Since the apparatus of Zuntz and Schumberg measured both the oxygen consumed and the CO_2 exhaled it provided data to determine the respiratory quotients. Knowing these one could, with a complete table, measure the actual calorie production of an individual under a great variety of environmental conditions.

Modifications of the Zuntz "respiratory calorimeter" have been developed in this country by Francis G. Benedict, and others, and machines are now available which are suited for all sorts of conditions. None of them are suitable for long continued use, but by taking frequent short periods the twenty-four-hour requirement may be approximated. The machines are also suited for observation of the effect of environmental variations such as severe muscular effort for a period, the effect of drugs, or pathological states, etc. Such use is called the indirect calorimetry method.

DIRECT CALORIMETRY

Atwater, Rosa, and Benedict have devised an apparatus in which the individuals actually could be enclosed and the heat elimination over a long period of time measured. Benedict also has con-

structed various modifications of this type of calorimeter. With such apparatus much valuable data also have been added and Lusk has summarized some of the results obtained by the various calorimeters as follows:

Twenty-four-hour mean energy requirement of average-sized man (after Lusk)

	Calories
Absolute rest in bed without food	1680
Absolute rest in bed with food	1840
Rest in bed eight hours, then sitting in chair sixteen hours, with food	2168

These figures show that even when we are doing no voluntary work we are burning some food just to keep our body alive, that the digestion of food uses some calories, and that so small an effort as is needed to keep the body in a sitting instead of a prone condition has its calorie requirement.

BASAL METABOLISM AND ACTIVITY METABOLISM

If an individual's calorie requirement is known, when the individual is empty of food, and prone and at rest, and it is also known how many calories it is necessary to provide for every type of energy that may be needed in a twenty-four-hour day, then by a mere summation of these data can be determined the measured requirement for twenty-

TABLE 7

Energy expenditure per hour per pound of body weight

(After Sherman and Rose)

FORM OF ACTIVITY	CALORIES PER HOUR PER POUND OF BODY WEIGHT
Sleeping	0.43
Awake lying still	0.50
Sitting at rest	0.65
Reading aloud	0.69
Standing relaxed	0.69
Dressing and undressing	0.81
Tailoring	0.88
Typewriting rapidly	0.91
Ironing	0.93
Sweeping bare floor	1.09
Carpentry	1.56
Walking moderately fast	1.95
Sawing wood	3.12
Running (5.3 miles per hour)	3.70

Calculations possible from such data

Total 24-hour requirement of a 150 pounds male carpenter

	calories
10 hours' sleep	650
1 hour awake lying still	77
1 hour dressing and undressing	118
2 hours walking slowly	400
8 hours carpentry	1920
2 hours sitting at rest	200
Totals 24 hours	3365

TABLE 7—*Continued*

Estimates of calorie requirements of children involving combination of basal energy determinations and activity needs

AGE	CALORIES PER POUND OF BODY WEIGHT
Under 1 year	45
1–2 years	45–40
2–5 years	40–46
6–9 years	36–32
10–13 years	34–30
14–17 years	30–23
18–25 years	25–18

four hours. The first measurement is spoken of in technical terms as a person's basal requirement or "basal metabolism." Sherman defines it as follows:

> The term "basal" metabolism is used to designate the rate of energy metabolism of the body when at complete rest in a room of ordinary comfortable temperature, and when the observations are made in the so-called "post-absorptive" state, i.e., twelve to eighteen hours after the last intake of food.

In the basal metabolism determination will be found most of the individual peculiarities that distinquish the calorie needs of one person from those of other individuals. The activity values are fairly constant for all individuals at a particular

kind of work. In recent years particular attention has been given to basal metabolism determinations, for these enable us to construct fairly accurate requirements for groups of individuals of the same age and habits of life. The value of some activity factors is presented in table 7.

PREDICTION FORMULAE

The exact measurement of individuals in a calorimeter is a slow and tedious calculation. The relation of the calorie requirement to the surface area of the body earlier suggested a means of expressing or predicting calorie requirements by measuring body surface and then applying a factor. Various such formulae have been developed of which the following are often employed:

Let A be the body surface in square centimeters desired.
Let H be the height measured in centimeters.
Let W be the weight measured in kilograms.
Let 71.84 be a constant whose logarithm is 1.8564.

With this data the value of A can be calculated by using either of the following:

$$A = W^{0.425} \times H^{0.725 \times 71.84}$$

or

$$\text{Log } A = (\log W \ 0.425) + (\log H \times 0.725) + 1.8564$$

Correlating the values of body surface obtained with this formula with direct calorimeter measurements and variations in age DuBois obtained the average relations of basal metabolism values to surface shown in table 8. These data are very tempting. With them we have only to measure

TABLE 8

DuBois standards of prediction

AGE	CALORIES PER SQUARE METER OF BODY SURFACE PER HOUR	
	Males	Females
years		
14–16	46.0	43.0
16–18	43.0	40.0
18–20	41.0	38.0
20–30	39.5	37.0
30–40	39.5	36.5
40–50	38.5	36.0
50–60	37.5	35.0
60–70	36.5	34.0
70–80	35.5	33.0

weight and height in the proper units, insert them in the formula and solve for body surface. Then multiply the result by the values in table 8. Unfortunately, this assumes that the tables are absolutely correct and as calorimetry proceeds the prediction values are seen in many cases to

be too high or too low. Table 9 gives data from the work of Dr. Grace MacLeod which illustrates the need for such checks. The practical result of these studies was to show that if we feed girls of eleven and twelve years of age on the basis of the prediction figures we shall be wasting money, for they do not need so much food; but that if we

TABLE 9

*Studies of the normal basal energy requirement**

Girls 11 to 14 years of age

AGE	CALORIES PER SQUARE METER OF SURFACE PREDICTED BY USE OF FORMULAE	VALUES ACTUALLY FOUND BY DR. MACLEOD IN MEASURING NUMBERS OF GIRLS OF THESE AGES
11	40.8	37.5
12	37.7	41.3
13	37.8	41.0
14	43.0	36.6

* From the dissertation of Dr. Grace MacLeod, Columbia University, 1924.

follow the prediction figures for the twelve- and thirteen-year-old's we will be giving them less than they ought to have to meet their needs.

Further, basal metabolism figures obtained by measurement are not necessarily always constant for a group. We know that the nature of the food we eat can change this value and that proteins or

meat foods for example will, if increased above a certain amount, actually raise the basal requirement. Eating more meat makes it necessary for us to eat more of other food to supply the energy to perform a given amount of work. Disease conditions may also influence the rate, and basal metabolism in fever and in thyroid disease may be quite different from the normal.

Enough has been said to show that the accurate measurement of calorie requirements is still in process of development. Standards now existing are sufficient for a working basis but it is to be hoped that the study of calorie requirements is no longer considered unimportant. There never has been a time in nutrition science when more care was being expended to enable us to provide adequately for the fuel needs of our bodies or to learn what those needs are.

THE CALORIE VALUE OF NUTRIENTS

Assuming that we can from the data presented know at least approximately how many calories we need per day, how shall we translate this knowledge into weights and volumes of common foodstuffs?

Since food is burned in the body and thereby

produces heat it would seem just to assume that the amount of heat given off by a food, when burned outside the body, is a true index of its fuel value to the body. We can get at such values by use of an instrument called a bomb calorimeter. This apparatus consists of a small chamber into which a weighed sample of food can be placed. The space about the food is then filled with pure

TABLE 10

Bomb values for pure nutrients and the values after correction

PURE NUTRIENT	BOMB CALORIMETER VALUE OF 1 GRAM	HUMAN CALORIE YIELD OF 1 GRAM
	calories	*calories*
Carbohydrate	4.1	4.0
Fats	9.45	9.0
Proteins	5.65	4.0

oxygen gas. The chamber is so jacketed as to make all the heat generated by the combustion of the food go to the raising of the temperature of a given volume of water. From the temperature change, and the known volume of water and food, we can then calculate the actual amount of calories generated by the combustion of a gram or pound or ounce of a given foodstuff. Unfortunately, the

figures thus obtained are higher than result from the combustion of these foods in the body. A gram of pure protein in the bomb calorimeter yields 5.65 calories, while it is now known that the same amount if ingested by man would yield to the body only 4 calories. When we eat a food, there is a little loss of combustible materials in digestion. Also certain foods, like proteins, are only partly burned in the body. For that reason it has been necessary to correct the bomb calorimeter values for these various losses. Table 10 gives the actual bomb values for pure nutrients and the values after correction.

In view of these facts it will follow that the calculation of the calorie value of foods can be better obtained by use of composition tables and the factors given in the second column of table 10. Take the following example:

From the analytical tables we find that the composition of average white bread is expressed as follows:

	Per cent protein	*Per cent fat*	*Per cent carbohydrate*
White bread*..	9.2	1.3	53.1

* A pound of bread weighs about 450 grams.

	Calories
9.2 per cent of 450 grams is 41.4 grams protein which multiplied by 4 gives	165.6
1.3 per cent of 450 grams is 5.9 grams fat which multiplied by 9 gives	53.1
53.1 per cent of 450 grams is 239.0 grams carbohydrate which multiplied by 4 gives	956.0
Total calories in 1 pound bread	1174.7

A pound of bread thus yields us about 1175 calories, if the chemical analyses are correct. In many tables now available the chemist has done all this calculating for us. He has analyzed the food as purchased and its edible portion and he has calculated the nutrient per cents and the calorie values of each. Table 11 is an extract from Sherman's *Chemistry of Food and Nutrition* which illustrates both the method and a source of such data.

It should be noted, however, that the values of pure nutrients upon which the Sherman tables are based, viz., 4 calories per gram of protein or carbohydrate and 9 calories per gram of fat are a little lower than used to be assumed correct. In the United States Department of Agriculture, Bulletin No. 28 (Revised Edition), which is much used as a source of analytical data regarding foods the calorie values are all calculated on the assump-

tion that 1 gram of protein or carbohydrate in the body yields 4.1 calories and that 1 gram of fat yields 9.3 calories. These figures are now known to be too high. Consequently if these tables are used the calorie value should be corrected. Modern texts carry such corrections.

It will now be clear that with the food composi-

TABLE 11

Analysis of sirloin steak

		PER CENT OF PROTEIN	PER CENT OF FAT	PER CENT OF CARBOHYDRATE	FUEL VALUE PER POUND	100 CALORIE PORTION IN GRAMS
Sirloin steak..............	E.P.	18.9	18.5	—	1,099	41
	A.P.	16.5	16.1	—	960	48

* E.P. and A.P. indicate *"edible portion"* and *"as purchased."* It takes 28.35 grams to make 1 ounce avoirdupois.

tion tables and the calorie requirement tables we have enough data to translate food quantities into calories and measure our daily needs in terms of food purchase It is, however, freely admitted that few American families can be expected to make the calculations necessary for the exact mathematical apportionment of exact calorie value in foodstuffs for the day's diet. For that reason

many textbooks in nutrition are trying to teach people how to estimate the calorie value of foods through study of tables that express these values in common units of such foods (see table 12).

It may be in time that such information as is given in table 12 will be as common as is the knowledge of weights and measures. The acquisition of such knowledge is well worth while. We realize that most people will not take the time to actually calculate the calories they feed either to themselves or their children. In default of such calculation, probably the safest procedure for the ordinary person is to watch the scales and their general health. Try to adjust the quantity of food to the maintenance of proper weight, and if

TABLE 12

*Calorie values of certain foods**

FOODSTUFF	AMOUNT NECESSARY TO PROVIDE 100 CALORIES		
	Grams	Ounces	Common unit
White bread	38	1.34	2 slices 3 in. x $3\frac{1}{2}$ x $\frac{1}{2}$
Cheese, American	23	0.8	1 and $\frac{1}{8}$ in cube
Milk	145	5.1	$\frac{5}{8}$ cup
Peaches	290	10.5	3 medium-sized

* Values are taken from *Feeding the Family*, by Mary S. Rose, published by Macmillan.

ill-health follows consult the necessary expert for advice.

An additional word of warning is necessary. Over-weight, especially after one has reached forty years of age is prone to develop because one's activities begin to decrease at that age. Eating habits are then so established that one does not reduce the food intake with the reduction in activity. One then begins to "get fat," and to worry about it. Unfortunately, advertising literature is full of get-thin-easy cures and some of these are pernicious in their possible and actual effects on health. No one should attempt to cure oneself of a tumor or disease. If an increase in weight is noted in spite of a moderate reduction in food intake, do as one would in case of any physical condition about which one's knowledge is lacking, consult medical authority and be guided by their directions.

CHAPTER III

The Protein Requirement

The primary function of diet is to supply the fuel with which to run the human activities. It has been shown that there is a certain basic consumption of calories to maintain life when the body is at rest and that this consumption is increased in direct proportion to the amount of activity. Use of the information outlined in Chapter II makes it possible to secure an amount of digestible food that will supply the calories needed by any type of individual.

The body, however, is more than a consumer of fuel. It is continuously undergoing breakdown and repair of its component parts. In infancy and youth the construction is in excess of the breakdown and there is steady increase in size and weight. We call this growth. In adult life growth has practically ceased but breakdown has not and hence, even in adult life, the consumption of food must keep pace with the breakdown in order to maintain weight and normal function. Growth and repair then create another function

of food which is more or less independent of activity. The engine must be kept whole whether it is in active use or idle part of the time.

The problem of what foods to eat to provide body parts and what to furnish fuel would be much simpler to state if the nutrients were divisible sharply into energy foods and body-building foods. Not so many years ago the German chemist Liebig thought that proteins were used only for body building and that fats and carbohydrates were solely for energy. Today many texts still call proteins *body builder* and class sugars, starches and fats as *energy foods*. We know now that proteins may be used to supply calories and frequently are; that fats and carbohydrates are often used to manufacture essential parts of our bodies and are not burned for fuel in such instances. These facts make it difficult to state sharply the requirement of any particular nutrient. Take protein, for example, one can see that an amount necessary to make all the body's repair might fail to accomplish this purpose if we fail to supply enough other food to furnish the requisite fuel, for in that event part of the protein will be burned and unavailable for construction purposes.

There are other difficulties in stating definitely

the body's protein requirement. During youth, growth creates demands in excess of that needed for repair and the rate of growth will vary the demand. For females the period of pregnancy, or lactation, may create temporary needs much in excess of normal requirements and diet will have to be changed to satisfy these special demands. But

TABLE 13

Suggested nutrient standards

NUTRIENT	VOIT, GERMAN PHYSIOLOGIST FOR MAN AT MODERATE WORK	ATWATER, AMERICAN PHYSIOLOGIST	CHITTENDEN AMERICAN BIO-CHEMIST FOR MAN WEIGHING 150 POUNDS
	grams	*grams*	*grams*
Protein	118	125	60
Fat	56	—	—
Carbohydrate	500	—	—
Calories	3,086	3,400	2,800

One ounce equals 28.35 grams.

there is still a greater difficulty. The protein analyses of foods such as were given in the preceding chapter tell simply the amount of protein in a food and nothing of its biological value, i.e., its utilizability by the body. Such figures assume that all proteins are alike in value but they are not. Even if we could assume that 75 grams of protein per day were adequate for an individual

who is using milk to supply that protein, it does not follow that 75 grams of bean protein would produce the same effect. In fact, we know today, it will not. Add to this the fact that certain proteins of low biological value become of excellent value when combined in the diet, while other mixtures are quite inadequate, and the complexity of factors involved in telling us how much protein to eat become evident.

Within the past twenty-five years three distinct standards for protein intake have attracted wide attention and are often cited in text-books (see table 13). Those of Voit and Atwater were based on statistical studies and are really records of performance rather than requirements. Chittenden's figures were issued as the result of a profound conviction that the American people were prone to eat too much protein and that such consumption actually tended to decrease both mental and physical stamina. Chittenden states:

> Greater freedom from fatigue, greater aptitude for work, greater freedom from minor ailments, have gradually become associated in the writer's mind with this lowered protein metabolism and general condition of physiological economy.[1]

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[1] Russel Chittenden, *Physiological Economy in Nutrition*, p. 51.

It may be recalled by some that in olden days the training tables of athletes groaned with rare roast beef, the idea being that meat made muscle. It was Chittenden who first dispelled this fallacy and taught that athletes could be trained effectively on a much lower amount of protein than had been supposed possible. Chittenden also thought at the time that he had proved conclusively that 60 grams per day was enough for any individual of the size and age noted, but we know today that in providing calories from vegetable and other sources he introduced into the diet factors at the time entirely unsuspected, and we do not know today whether the improvements Chittenden actually obtained by reduction in protein were due solely to that reduction.

In recent years Sherman has collated data giving a wider and more complete picture of American practice in protein consumption than Atwater possessed. By an analytical study of 224 typical American dietaries Sherman found the following averages indicated:

Protein........ 106 grams of 424 protein calories per day
Calories........ 3256 per day
Protein was 13 per cent of the total calorie intake.

Before discussing these protein standards further, let us consider certain experimentally established facts. It is now abundantly established by various methods of measurement that the human adult can reduce his intake of protein per day to as little as 50 grams, and with that intake meet all the body-building requirements which involve protein. Many hold it adequately demonstrated that if the body's energy needs (calorie needs) be adequately met by fat and carbohydrate, increased activity does not require increase in protein consumption. In other words, that the man whose energy requirement is 4000 calories actually requires no more protein than the man whose energy need is 2500 calories. Fifty grams a day will satisfy either if the calories are supplied by other nutrients.

All the experts, however, realize that the determinaton of exact requirement involves the evaluation of many factors that have not as yet been adequately measured. Perhaps then, there is no better way of indicating present views about protein requirement than to quote a few representative opinions that have appeared in print in the past two years.

Protein requirements. The amount of protein which the daily diet should contain has been the subject of much discussion. It was formerly assumed that a man of average size required about four ounces of protein daily. It is now known that not more than half this amount if of good quality will suffice for the repair of his daily loss of protein from the muscles and other structures. The amount which is best for promoting physiological well being over a long time has not been fully established, but it seems certain that if foods are so chosen that their proteins fit together and make a mixture having a high biological value, a smaller amount will suffice than would be required if the proteins have a low value. If the foods are properly chosen, and the diet contains sufficient milk, eggs, cheese, and meats, probably seventy-five grams a day is a safe intake. The special problem is to secure a diet in which the protein content is relatively high but which will not permit of protein putrefaction in the intestine. There can be little doubt that excessive protein consumption is to be condemned, but all studies on animals indicate that a fairly liberal protein intake is better than an abstemious regimen.—E. V. McCollum and Nina Simmonds, *Food Nutrition and Health*, published by the authors, Baltimore, Md., 1926.

It is often convenient to express this (protein requirement) in terms of total day's fuel. An allowance of two calories per pound for a man of average weight means about 300 calories per day. If his total energy requirement is 3000 calories, this means approximately 10 per

cent of his fuel in form of protein. Two and one-half calories per pound for a man consuming 3000 calories would mean about 15 per cent of his fuel as protein. A higher proportion results in more loss of heat from the stimulating power of the protein, so that in general the body need seems best met by supplying from 10 to 15 per cent of the total fuel in the form of protein, except when the man is in bed, in which case care should be taken that he has at least two calories per pound.

The housewife who provides a somewhat varied diet, ample in fuel value, including milk and eggs, need not feel that she is depriving her family of any essential if she furnishes a very small amount of meat or none at all. One-fourth of a pound a day as an average for each adult man will provide approximately one-third of his protein requirement; bread, cereals, fruit and green vegetables will furnish another third; and the remainder can be obtained with little difficulty from a glass of milk, an egg, some cheese, beans or nuts.—Mary S. Rose, *Feeding the Family*, Macmillan, 1924 edition.

Little can be said with confidence regarding the best amount of protein for children after the nursing period. In practice well planned dietaries for children usually contain between 10 and 15 per cent of the total energy in form of protein. During the years of rapid growth a considerable fraction of the protein of food is utilized in the synthesis of body protein; and since the amount of food protein required to form a gram of protein is variable, depending upon the amino acid make-up of the former,

it is evident that the kind of protein supplied becomes a matter of great importance. Here, chemical and physiological laboratory evidence, clinical experience, and its evident place in nature, all indicate plainly the superiority of milk as a source of supply of protein for growth, whether the case be that of the growing child after weaning or of the nursling fed through the mother. In cases where the nutritive requirements of growth, pregnancy, or lactation are to be met, the kind of protein is perhaps as important as the amount. The recommendation that family dietaries should wherever possible include "a quart of milk a day for every child" was aimed primarily to ensure an adequate protein supply. Needless to say, the milk also supplies important amounts of many other substances essential to growth.

Since the energy requirement is greatly increased by muscular activity and the protein requirement is not, it is evident that in metabolism of normal adults the energy and protein requirements will not run in parallel. The protein requirement of the healthy adult depends chiefly upon his size, while his energy requirement depends chiefly upon his activity.

In childhood both the energy requirement and the protein requirement are high—often two or three times as high per unit of weight as for adults without muscular work. Moreover the high protein requirement and energy requirement of the child as compared with the man are found to run approximately parallel and, as shown in a previous chapter, the same proportion of protein in terms of total energy that seems rational for the adult

dietary suffices also for the food requirements of the child, provided in the latter case the food is of the appropriate kind.

In most family groups the differences in age and size will constitute a more prominent factor than the differences in activity, and since the former affect energy and protein requirements in about the same proportion, it seems feasible and convenient to set the protein allowance for ordinary family groups in terms of a proportion of the total energy. To allow for varying conditions and for individual preferences as well as to provide a liberal margin for safety it is customary to consider that from 10 to 15 per cent of the total calories may be in the form of protein. —H. C. Sherman, *The Chemistry of Food and Nutrition*, Macmillan, 1926 edition.

Many years have elapsed since the demonstration that individual proteins differ profoundly in their chemical make-up and in their nutritive value for animals. Numerous feeding experiments have shown that the mixtures of proteins occurring in natural foods and feeds, and the commercial products prepared from them, also differ distinctly in nutritive value, while recent chemical studies have indicated that such differences may be expected from the different proportions of amino acids contained in them. However, the protein requirements of animals are still stated in terms of a given weight of digestible food protein per unit of weight of animal or product, a survival of the time when chemical differences were unknown or unappreciated. Such a statement is incongruous with

present day knowledge, but at present no other statement is possible because of the fact that precise information concerning the protein values of feeds and mixtures of feeds is not at hand.—H. H. Mitchell, *Bulletin National Research Council No. 55*, March, 1926.

These quotations present both advised practice and defects therein. If we accept Sherman's advice we will proceed as follows: First find out what is our energy requirement, take 10 or 15 per cent of it and divide the value by the number of calories in a gram of protein. This will give us an upper and a lower amount of protein in units of weight. Do not go below the lesser amount or over the upper amount. Thus:

Energy requirement: 3000 calories
10 per cent is 300
15 per cent is 450

300/4 gives 75 grams protein necessary to supply 300 calories
450/4 gives 112 grams protein necessary to supply 450 calories

Do not eat less than 75 grams or more than 112 grams.

We should not, however, follow his advice entirely until we have made sure that the protein we eat is of the right kind or quality. How can we determine that?

We should know more of protein structure to

understand how quality is determined and really to appreciate the terms and conditions expressed in the quoted opinions. Let us then devote the next chapter to a consideration of protein structure and quality.

CHAPTER IV

What Is Protein and What Is Meant by Protein Quality?

Meat, cereals, eggs, milk, cheese, and fish were found early in man's nutrition discoveries to consist in part of chemical compounds which when burned yielded no ash or mineral component and which always contained the chemical element *nitrogen.* These compounds were later found to differ in solubility and in various other physical characteristics, but they never failed to contain nitrogen, and as they were separated from their various sources the nitrogen was found almost always to constitute about 16 per cent of the total weight of the compounds.

The nitrogen content and a combination of test signs soon enabled chemists to recognize and to determine the amount of these compounds in foodstuffs. In most tables of nutrient content you will find under the caption "Per cent protein" the following: "N $\times$ 6.25." If you will divide 16 into 100 the quotient will be found to be 6.25, and the caption N $\times$ 6.25 means

that it is now common practice for the chemist to analyze foods for nitrogen and multiply the result by 6.25 to get the amount of protein, on the assumption that the nitrogen in most foods is protein nitrogen and that all proteins average 16 per cent of that element.

In the days of Liebig it was known that proteins are nitrogenous compounds, the nitrogen forming about 16 per cent and the rest of the protein being composed of carbon, hydrogen, and oxygen, with occasionally a little sulfur or phosphorus in the molecule. It remained, however, for a German chemist by the name of Kossel to first demonstrate that the large protein molecules were built like a jeweler's fancy chain by combining smaller nitrogen compounds which we may liken to the separate links of the chain; and that these compounds or links could be separated and identified. To date twenty or more such links or simple compounds have been separated and identified and since they are all acid in reaction the chemist has called them *amino acids*. Kossel showed the similarity of proteins, regardless of source, to be due to their being composed of similar amino acids and that the differences in proteins lie in the variation in kind and amount of the various amino

acids of their make-up. To use our chain analogy again it was possible for nature, like the jeweler, to make many different protein chains by varying the proportions and kinds of links.

Kossel's viewpoint was confirmed by another great German chemist, Emil Fischer, who took simple amino acids and actually combined them in the laboratory into a product that responded to all the protein tests, though the ones he made were unlike any found in nature up to that time. In recent years further evidence has accumulated through the synthesis of compounds called "plasteins." Certain enzymes were known to digest or split proteins into amino acids. Starting with such digestion mixtures chemists learned how to reverse the action of the enzymes and build the amino acids up into substances giving all the known protein tests. These synthetic proteins were labeled "plasteins." At one time doubt was cast on their being true proteins from the nutritive viewpoint but recent feeding tests show that they meet all the protein needs of animals when given as the sole protein in the diet.

Table 14 gives the names that have been assigned to the amino acids identified to date. It also gives the proportions of these found in a few com-

TABLE 14

*The amino acid content of some common proteins**

NAMES AND AMOUNTS OF CERTAIN AMINO ACIDS IN CERTAIN NATURAL PROTEINS	MILK CASEIN	EGG ALBUMIN	BEEF PROTEIN	GELATIN	WHEAT GLIADIN	CORN ZEIN
	per cent	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*
Cystine	0.50	2.13	1.55	0.31	2.32	0.85
Histidine	2.84	1.71	1.76	0.90	3.35	0.82
Lysine	7.62	3.76	7.59	5.92	0.92	0.00
Tryptophane	2.20	3.64	1.25	0.00	1.14	0.00
Arginine	3.81	4.91	7.47	8.22	3.14	1.82
Proline	7.63	3.56	5.82	9.50	13.22	9.04
Tyrosine	6.50	1.77	2.20	0.01	3.50	3.55
Phenylalanine	3.88	5.07	3.15	1.40	2.35	6.55
Glycine	0.45	0.00	2.06	25.50	0.00	0.00
Alanine	1.85	2.22	3.72	8.70	2.00	13.39
Valine	7.93	2.50	0.81	1.00	3.34	1.88
Leucine	9.70	10.71	11.65	7.10	6.62	19.55
Oxy-proline	0.23	?	?	14.10	?	?
Aspartic acid	4.10	2.20	4.51	3.50	0.58	1.80
Glutamic acid	21.77	9.10	15.49	5.80	43.66	26.17
Oxy-glutamic acid	10.50	?	?	0.00	2.40	2.50
Serine	0.50	?	?	0.40	0.13	1.02
Ammonia	1.61	1.34	1.07	0.49	5.22	3.64

* Taken from Sherman's *Chemistry of Food and Nutrition*, Macmillan, 1926.

mon proteins of natural origin. A study of this table will show that while many of the seventeen amino acids listed in these analyses are found in all the proteins named, the proportions vary and in certain instances particular amino acids are entirely missing. Gelatin, for example, has no tryptophane at all while wheat gliadin has very little lysine.

It would be impossible, within the compass of a popular treatise, to trace all the physiological consequences of this variation in amino acid content. Suffice it to note that we now know digestion of protein to be a process of separating food proteins into their individual amino acids and the transfer of these acids into the blood; that the blood then carries these separated amino acids to our tissues, and that in the tissues they are recombined into entirely different proteins. The cow, for example, eats grass protein and digests it. Her tissues then recombine some of these acids into beef protein. We eat beef protein and digest it and our tissues recombine the amino acids into human muscle protein.

The next important question is whether our food must supply all these amino acids or whether our body could manufacture some of them out

of the elements. Again we know today that the body can probably make several of them and that to omit these from our diet would not prevent our construction of body proteins. *But,* and this is significant, we know with equal certainty that the body cannot make *cystine, histidine, lysine* or *tryptophane,* and that if the proteins we eat do not contain these particular amino acids in sufficient quantity, body proteins essential to life will not be produced.

The experiment of de Vaux during the Paris Revolution in substituting gelatin for beef and its failure now becomes intelligible. If you will look at the table you will see why the experiment failed; we cannot make body protein without tryptophane *and gelatin contains no tryptophane.*

T. B. Osborne and L. B. Mendel have taught us much of what we know today about the physiological significance of the various amino acids. In recent years that knowledge has been much extended by various workers (notably McCollum, Sherwin, Rose, and Lewis). We are gradually accumulating definite facts about what amino acids we must eat and what will happen if we omit them from our daily diet.

It was Osborne and Mendel for example who showed by rat-feeding experiments that these animals would live and grow when milk casein was their sole source of protein, that they would live but fail to grow when wheat gliadin was substituted for casein, and that gelatin or corn zein would allow them neither to grow nor live. Further, they showed that for both maintenance and growth lysine and tryptophane are necessary and that while lysine was not essential to maintenance it was necessary to growth. They confirmed these views by the following experiments: They restored rats of suspended growth on a ration of wheat gliadin either by adding pure lysine to the ration or by adding gelatin or some other protein which contained lysine. On the other hand they showed that the addition of gelatin to rats on corn zein as a source of protein failed to prolong life, for while the gelatin supplied the lysine which the zein lacked neither zein nor gelatin contains any tryptophane.

With these explanations, some of the difficulties in prescribing protein requirement referred to in the preceding chapter become intelligible. Also some of the phrases in the opinions quoted. We can understand now what McCollum means by

"good quality," and by saying "if foods are so chosen that their proteins fit together and make a mixture having a high biological value." Evidently "fitting" and "biological value" depend upon our combining proteins which supplement one another's lack of essential amino acids.

Also, since the proteins of milk, meat, eggs, and cheese are rich in *all* the essential amino acids, while those of cereals are not, it is the part of wisdom to see that in selecting our protein requirement from natural foods we insure against amino acid deficiency by including in every day's diet enough milk, eggs or meat to obtain protection against the possible deficiencies of cereal or vegetable proteins. Especially is this important if we reduce our total protein intake to near the minimum requirement.

A protein of *good quality* or of *high biological value* will then contain all the essential amino acids necessary to the construction of body proteins. A protein mixture of good quality may contain proteins that are individually of poor quality, provided these are so chosen that the lack of essential acid in one is met by abundance in the other. Such a mixture may be as utilizable as a single good protein.

The individual who relies on white bread f protein will lack the growth factor lysine, but if gelatin dessert is eaten with it, the abundance lysine in the gelatin may make up this inad- quacy and the mixture prove satisfactory. O the other hand if corn bread is used for protei the gelatin dessert will only partly meet the nee and the mixture still prove inadequate.

You will see now why, in view of the larg amount of bread eaten, nutrition experts ar interested in experiments with breads made from milk instead of with water, for the milk protein is our richest source of the lysine which the white flour protein lacks, and inclusion of milk in the bread tends to make the mixture adequate in protein quality.

Many other examples might be cited of how this study of quality in individual proteins enters into our judgment of protein adequacy of diets. Let us now recall the opinion of Mitchell, cited in the last chapter. He said in regard to prescribing protein in terms of amounts: "At present no other statement is possible because of the fact that precise information concerning the protein values of feeds and mixtures of feeds is not at hand."

Mitchell's remark was made in connection with animal feeding, but by it Mitchell calls attention to the fact that while we know how to combine proteins to secure adequate amounts of amino acids we have still much to learn about the physiological effects of mixtures. To take a sample example that will be significant to every layman, let us cite the recent study of the legitimacy of adding gelatin to ice cream. Many state laws prescribe the amount of gelatin that may be in the cream and this prescription was made originally to prevent the unscrupulous manufacturer from securing non-melting and smoothness in his article through the substitution of gelatin for real cream. Recently, however, Downey and his co-workers at the Mellon Institute have found that a small amount of gelatin added to milk may actually increase our ability to use the milk protein. This improvement cannot be due to any amino acids added by the gelatin, for milk contains all that are in gelatin. Downey believes the improvement to be due to another function of the gelatin. Mothers know that barley water is often added to baby milk formulae as a diluent to make it more digestible, that is, to prevent the formation of large milk curds in the baby's stom-

ach. Downey finds that gelatin, like the barley water, has this property of preventing the formation of large milk curds. By reducing their size it allows the digestive juices to act more quickly and completely and thus more casein is digested and absorbed. Such a purely physical power of gelatin makes it an aid to digestion and its use in ice cream may be justified on that basis. We may consider it an adjuvant instead of an adulterant.

Again McCollum notes that bean proteins are not as valuable in the diet as milk and egg protein. Breese Jones, however, has explained this as due in part to a substance (gossypol) found in the beans which hinders the digestion of the bean protein and that their lower quality is due to the presence of this substance rather than to their lack of essential amino acids. He also showed that cooking tends to reduce the hindering action of the substance and to make the bean protein more available.

The two discoveries cited are comparatively recent acquisitions to the science of nutrition. They suggest that Mitchell is right in warning us that we have as yet too insufficient data on the influence of mixtures to be sure of the protein value of food combinations, and that much experimenta-

tion is necessary, even though we may know the amino acid content of the individual proteins in the mixtures.

Perhaps it is well to emphasize again the advice given in the quoted opinions and in the text preceding, that to insure the proper amount and kind of protein in the daily diet the best insurance for the layman lies in eating every day some proteins of proved quality. Of these there is no question that milk provides the best protein known to nature, and that meat, fish, and eggs also contain those of good quality. Conversely it will be clear that it may be dangerous to adhere too closely to a purely vegetarian diet unless the mixture has been compounded so as to meet all deficiencies in protein quality.

CHAPTER V

How Much Fat and Carbohydrate Should We Eat?

Much more attention has been given to estimating total calorie requirement and protein need than to the specific question of how much fat and carbohydrate should we eat. If we fix these two values and say 3000 calories per day and 75 grams of protein, it follows that since 75 grams of protein furnishes only 300 calories, our diet for that day must contain 2700 calories of fat and carbohydrate mixture; this because aside from protein they are our only sources of calories left. For this reason many have suggested solving the problem in the following way: Given the energy requirement, first provide the protein and then make up the remaining calories in either fat or carbohydrate, letting pocket-book and taste be the guides in regard to the proportions of each. Such advice, however, leads to very different practices in different geographical regions, Americans eat more fat than Orientals, but much less than the Eskimos.

Voit is one of the few who have made any definite suggestions about proportion, and his suggestion is based on practice rather than on evidence of its being optimum. For a man at moderate muscular effort, Voit called for 118 grams of protein, 56 grams of fat and 500 grams of carbohydrate. Fifty-six grams of fat supply 514 calories, and 500 grams of carbohydrate yield 2000 calories, so his ratio would be 1 fat calorie to every 4 carbohydrate calories or 1 part of fat for every 9 parts by weight of carbohydrates eaten.

Sherman devotes very little space to this particular problem, but what he says is significant of probable need of more attention to the problem.

All competent students of the question are agreed that fats and carbohydrates are iso-dynamically interchangeable within wide limits, but not to an unlimited extent. In the matter of emphasis, as distinguished from fundamental opinion, we find differences even among the highest authorities, Hopkins having recently emphasized the idea of caution in accepting the "so-called law of isodynamic equivalence," while Osborne and Mendel have described experiments in which they obtained good nutritional results both with diets practically devoid of fats and with those in which carbohydrates were reduced to a vanishingly small proportion. In the actual feeding of people, the problem is probably more largely one of ex-

pediency than of actual nutritional need. During the world war the European nations found that a shortage of fat which reduced the available allowance to less than 75 grams per man per day was likely to cause not only discontent but a tendency toward a lowering of efficiency and morale, while their Oriental allies were entirely satisfied and highly efficient on even smaller amounts. This was probably not a racial difference in true physiological need but a matter of long-standing difference in habits and preferences.[1]

There is no question but that the fulfillment of the energy requirement is the first necessity in combining these factors, but it does not follow that the proportion of fat or carbohydrate used is a matter of indifference. It is also probably true that the figures given in Chapter II, based on the American "doughboy's" likes are typical of many American preferences and habits. (These may be recalled here as 4.73 ounces of fat to 18.2 ounces of carbohydrate or about one-fourth of the mixture fat, a figure considerably higher than Voit's estimate, since 4.73 ounces is 134 grams.) In fact, the figures given by Pearl for the years 1911–1917 in the United States are an average daily consumption per adult man of 120 grams, of pro-

[1] Sherman, *Chemistry, of Food and Nutrition,* Macmillan, 1926.

tein, 169 grams of fat and 541 grams of carbohydrate. Such figures show racial habit but certainly cannot be cited as proof that more fat or less fat would havè been less or more beneficial.

The problem has been complicated somewhat in the past by using the term fat in the sense of natural fat. In that case the amount of fat taken is no longer a question of pure calories, for natural fats contain certain vitamins which are essential to the diet. This point was realized and avoided by Osborne and Mendel in the experiments cited by Sherman in the preceding quotation. In their own report they say:

> By supplying the vitamins in concentrated forms we have studied the nutritive value of diets which were essentially devoid of true fats. . . . . Unless a minute amount of fat plays as important a rôle in the metabolism of the organism as do minute quantities of substances represented by the vitamins, it seems reasonable to assume that pure fats are dispensable constituents of the mammalian diet. We have already pointed out that the results of the foregoing investigations lead one to question seriously the contentions made, particularly during the recent war, that fats as such play some unique rôle in maintaining well being, and further (as Maignon supposes) that they play an important rôle in the utilization of protein—a rôle that carbohydrates are powerless to fill. On the

other hand, our experiments should not be construed to minimize the great value of fats as a source of energy in the usual human dietary, as well as their peculiar advantage in culinary procedures.[2]

Assuming that these investigators are right, and that we can satisfactorily secure our calories from carbohydrate alone, provided we supply the substances other than fuel that natural fats may carry, is it equally true that we could get all our calories from fats? The answer to this question is sharply "No!" We have learned that while carbohydrates are completely burned in the body, without the assistance of any other nutrient, the amount of fat that we can burn with equal completeness is determined in part by the presence of carbohydrate. Furthermore, if the carbohydrate is not adequate, the partially burned fat products enter the blood and prove distinctly toxic to the system. The diabetic presents such a case. Due to inability to use carbohydrate to any great extent, the diabetic's supply of fuel from that source is cut off. If it is attempted to meet this need with fat the latter fails to burn completely, and

[2] Osborne and Mendel, Report of the Carnegie Institution, Washington, D. C.

the partially burned fat products accumulate in the blood and coma and death result.

Obviously, in ordinary practice, a tendency to excess is toward carbohydrates rather than fats for financial reasons and from taste. Hence, it rarely occurs, except in infants whose milk constitutes their sole diet, that we are ever in danger of acidosis from this cause. It is worth noting, however, in connection with the problem raised at the beginning of this chapter and because infantile acidosis from this cause is now a matter of somewhat frequent occurrence.

Let us return to the main query once more. Is it true that while pure carbohydrates alone may serve to supply our calorie needs it makes no difference what form is used? In other words, are pure starch, pure corn sugar, pure cane sugar, and pure milk sugar equally valuable and utilizable as sources of energy?

Since all digestible carbohydrates are assumed to be converted by digestion into mixtures of three simple sugars known as glucose, fructose and galactose, and since each of these sugars contain exactly the same kind and amount of elements ($C_6H_{12}O_6$), and are converted by combustion into the same number of calories, it would seem to make

little difference which carbohydrates we use for fuel provided they are completely digested.

In other words, since starch becomes glucose by digestion, since cane sugar becomes glucose and fructose by digestion, and since milk sugar becomes glucose and galactose will it make any difference whether corn sugar or cane sugar or milk sugar is put in the coffee, or omit all three and supply the lack with an equivalent amount of starch?

Presented in this manner most of our readers will recall numerous controversial viewpoints, with the majority of opinion of today leaning to the view that they are iso-dynamic equivalents, to use a word which means "as sources of energy alone." Is the majority viewpoint justified?

It may be recalled that a few years ago it was assumed that protein requirements could be stated in weight of protein, on the assumption that all proteins were of equal quality or biological value, and that it was necessary to modify that view when it was learned that they differed in quality. To be sure these differences in quality concerned ability to form body protein and not to supply energy. Does it follow, however, that two substances which yield the same number of calories

in the bomb calorimeter will do so in the body? In recent years we are beginning to acquire evidence that so simple a substance as glucose may exist in several forms, and that not all of these forms will burn in the body. If that is true of glucose, may it not also be true of fructose and galactose which are known to differ from glucose in several physical particulars, notably taste?

The point it is desired to suggest here is that it may be dangerous to assume equivalence, even for fuel purposes, until we know more of how these substances behave in the body. We know today that the diabetic's blood may be saturated with glucose and in default of insulin the individual will be unable to burn it. Some have even gone so far as to say that insulin makes glucose burnable by changing its form, but we have as yet no absolute certainty of how insulin works.

The doubts expressed in the preceding paragraphs are not intended to cause confusion in the selection of energy nutrients, but merely to suggest the danger of dogmatism and the need of more light on the problem of this chapter. There are many other important questions to consider in selection of carbohydrates and fats, when we consider them from the basis of occurrence in nature,

but such consideration involves knowledge of other nutritional factors to be found in such natural foods and their specific rôle in diet, notably in the matter of mineral content, vitamins and behavior in the digestive tract.

In summary we may say that the general opinion seems to agree that protein should supply not more than 15 per cent of our daily calories and that the remaining 85 per cent must come from the non-protein nutrients; that is, fats and carbohydrates and usually by a combination of the two. When other factors are considered in diet, the solving of the problems raised by these factors will provide the information on which to base a practical selection of food fats and carbohydrates without requiring us to face practically the arithmetical proportioning of these two fuel foods.

CHAPTER VI

Inorganic Nutrients—Why Do We Need Them?

It has been shown that our body is provided with fuel and the means of renewing its cell structure by the organic nutrients, proteins, lipins and carbohydrates. None of these in the pure form contains any ash, although their natural sources such as meat, milk, eggs, cereals, vegetables, and fruits all yield ash on burning. This fact in itself suggests that nature has insured our consumption of certain minerals or inorganic matter, for practically we cannot secure the organic nutrients without eating the minerals. Are these minerals necessary and could we do just as well without them?

The expected answer is "No!" and the very fact that we possess bones which, when ashed, show the following mineral content explains a need for calcium, magnesium, fluorine, chlorine and iron:

Composition of bone ash

	Per cent
Tricalcium-phospho-carbonate	88.0
Magnesium phosphate	2.0

Composition of bone ash—continued

	Per cent
Calcium fluoride	0.3
Calcium chloride	0.4
Iron	0.1

It is also known that the blood owes its power of carrying oxygen to its iron content, while the thyroid gland will not function without iodine. Aside from these structural uses of inorganic elements they are necessary for many of our body functions, among which may be listed the power to keep certain substances in solution, aid in the activity of our enzymes, to produce clotting of blood and of milk. The rhythmic beats of the heart require a definite concentration of inorganic substances in the medium in which it works, and the control of body neutrality and of osmosis between cells and lymph are additional examples of their importance in body function. To date the elements of inorganic nature, given in table 15, have been found in the body of man.

Of these elements some (copper, zinc, arsenic, etc.) occur only in traces but others are much more abundant, and of these the metals calcium, sodium, potassium, magnesium and iron and the non-metals phosphorus, sulfur, chlorine and iodine are of particular interest and importance. Phos-

TABLE 15

*Inorganic elements found in human structures**

METALS	NON-METALS
Lithium	Hydrogen
Sodium	Oxygen
Potassium	Carbon
Calcium	Fluorine
Magnesium	Chlorine
Manganese	Silicon
Iron	Phosphorus
Copper	Sulfur
Zinc	Iodine
	Arsenic

* G. Bertrand and Macheboeuf, of the Institute Pasteur, have also reported recently that the pancreas contains nickel and cobalt and that these elements function in the activity of that organ.

TABLE 16

*Contrast in ash constituents of dog milk and dog ash**

SUBSTANCES	IN 1000 PARTS DOG MILK ASH	IN 1000 PARTS DOG ASH
Potassium oxide	149.8	114.2
Sodium oxide	88.0	106.4
Calcium oxide	272.4	295.2
Magnesium oxide	15.4	18.2
Iron oxide	1.2	7.2
Phosphoric oxide	342.2	294.2
Chlorine	169.0	83.5

* From Matthews' *Physiological Chemistry*, Wm. Wood & Co.

phorus may be supplied in part by proteins and lipins and we get our sulfur mainly from protein, but most of the inorganic elements with the exception of carbon, hydrogen and oxygen are derived from the ash or mineral part of our foods and enter the system as mineral salts. It is interesting to note that the ash of milk contains most of these essential mineral salts. In that connection Mathews gives the comparison shown in table 16 between the ash of young puppies and the ash of dog milk, showing both similarity of content and proportion. These few examples are sufficient to emphasize the necessity of giving attention to mineral salts in the selection of articles of diet. Do we need to pick foods to supply these mineral needs, or do we get enough when we choose natural foods to satisfy our protein and energy needs?

EXAMPLE OF CALCIUM

Sherman has given especial attention in recent years to our requirement for calcium. By various means he has arrived at the conclusion that the adult man should have at least 0.45 gram of calcium intake per day, and that safety demands a standard of *0.68 gram.* He finds that the pregnant and lactating female and the growing child

have still greater need for this element and recommends for the latter at least 1 gram per day. Do we ordinarily get this amount?

A study by Sherman of 224 typical American dietaries showed an average intake of 0.74 gram but the number that were below this requirement were so great as to cause him to state that calcium is the element most apt to be lacking in American diets today.

Recently the author was asked to criticize a prison diet for men at hard labor in a tropical country and found only 0.26 gram of calcium per man per day, though the diet was typical of what the population of that country usually eat. It was not surprising to find dental defects and other manifestations of the lack of this element in this group.

EXAMPLE OF PHOSPHORUS

Sherman has likewise put the phosphorus requirement at 0.88 gram per day and the standard as *1.32 grams*. His American families showed an average of 1.63 grams. This result might at first appear reassuring were it not for the fact that we have learned that the amount of phosphorus that we can use and need is conditioned to a degree

by the amount of calcium in the diet, and that with a low intake of calcium excess phosphorus may produce serious disturbance in the way of acidosis or other pathological effects.

These two examples then not only indicate need for attention to food selection from the viewpoint of mineral requirement alone but care that the elements are neither below requirement or too greatly in excess. In either direction may lie peril. This matter of balance has received especial attention in recent years, owing to progress in the study of regulation of blood neutrality.

ACIDOSIS AND ACID BASE BALANCE

Chemists know that the inorganic elements in solution have the power to form acids or bases (alkalies). The metals calcium, sodium, magnesium and potassium take the form of $Ca(OH)_2$, $Mg(OH)_2$, NaOH and KOH in water and these solutions turn red litmus blue, that is, are basic (alkaline). The non-metals such as phosphorus and chlorine form compounds such as H_3PO_4 and HCl, which in solution turn blue litmus red, and are acidic in reaction. A metal then is a potential base or base-former and a non-metal a potential acid-former.

In nature the metals and non-metals sometimes are combined as salts in such proportions that the tendency of their metals to form bases is exactly balanced by the tendency of their non-metals to form acids, and such salts in solution will be neither acid or basic but neutral. Common salt ($NaCl$) is such a substance. Its sodium tends to form the base $NaOH$ but its chlorine tends to form HCl, and the proportions are such that the base $NaOH$ is just neutralized by the acid HCl formed.

In general, however, it is true that if we burn a food and take the ash or non-burnable part and put it in water the solution will be basic or acid or neutral, in proportion as the metallic or non-metallic elements predominate. The solution is neutral only when the two kinds of elements are in exact equivalence as base-formers and acid-formers. This practical method enables us to tell with comparative ease whether a food is predominantly acid or basic in its effect. This explanation is essential to understanding the effect of eating certain natural foods.

A glance at table 17 will show that when the ash of such foods as meat and flour are compared, the acid elements predominate, hence eating these foods will increase our acids. Contrariwise in milk,

spinach and lemons the basic elements predominate. Note also that while fruits like lemons are sour to the taste, due to the organic acids they contain, these acids are destroyed in assimilation and the effect of the lemon is the effect of its ash which is basic, not acid.

What is called the ash, or the mineral part of food, is after digestion more or less absorbed into

TABLE 17

Comparison of ash of various foods

FOODSTUFF	PROPORTION OF ITS ELEMENTS IN PER CENTS								REACTION OF ITS ASH IN SOLUTION
	Base forming					Acid forming			
	Ca	Mg	K	Na	Fe	P	Cl	S	
Beef.....	0.012	0.024	0.338	0.084	0.0030	0.216	0.076	0.230	Acid
Flour*..	0.020	0.018	0.115	0.060	0.0010	0.092	0.074	0.177	Acid
Milk.....	0.120	0.012	0.143	0.051	0.0024	0.093	0.106	0.034	Basic
Spinach..	0.067	0.037	0.774	0.125	0.0036	0.068	0.074	0.038	Basic
Lemons..	0.036	0.007	0.175	0.004	0.0006	0.022	0.022	0.011	Basic

* White.

the blood. Study of the blood has shown that in health it is very nearly neutral in reaction (very faintly alkaline or basic by accurate measurement). If anything occurs to change this reaction, ever so slightly, to the acid side very serious results may occur. The coma and death of the diabetic result from the unburned fat-acids cast into the blood

TABLE 18

*List of foods that tend to produce acidity or alkalinity when eaten by man**

ACID FOODS	ACIDITY PER 100 GRAMS	BASIC FOODS	BASICITY PER 100 GRAMS
Bread, white	2.7	Almonds	12.38
Bread, whole wheat	3.0	Apples	3.76‡
Corn, sweet, dried	5.95	Asparagus	0.81
Crackers	7.81	Bananas	5.86‡
Cranberries	†	Beans, dried	23.87
Eggs	11.10	Beans, lima, dried	41.65
Egg white	5.24	Beets	10.86
Egg yolk	26.69	Cabbage	4.34
Fish, haddock	16.07	Carrots	10.82
Fish, pike	11.81	Cauliflower	5.33
Meat, beef, lean	13.91	Celery	7.78
Meat, pork, lean	11.87	Chestnuts	7.42
Meat, veal	13.52	Currants, dried	5.97
Oysters	30.00	Lemons	5.45
Oatmeal	12.93	Lettuce	7.37
Peanuts	3.9	Milk, cow's	2.37
Prunes, plums	†	Musk melon	7.47‡
Rice	8.1	Oranges	5.61‡
		Peaches	5.04
		Peas, dried	7.07
		Potatoes	7.19‡
		Radishes	2.87
		Raisins	23.68
		Turnips	2.68

* Data taken from article on "The Use of Basic Diets In the Treatment of Nephritis" by Sansum, Blatherwick, and Smith, *The American Medical Journal*, vol. 81, p. 883, 1923.

† The ash of these fruits is alkaline but because of substances that form hippuric acid in the body they increase the acidity of the urine.

‡ These foods have been found experimentally to be very efficient in reducing body acidity.

stream. The term "acidosis" (literally full of acid) was coined to express this tendency toward change in blood to the acid side. (See table 18.)

Fortunately, the blood is provided with remarkable defensive agents against invading acids of any sort; but it will be evident that if we persist in eating foods in which acid-formers predominate we subject the mechanism to continual activity, and if it breaks down acidosis will result. A diet too high in meats and cereals always needs to be balanced by a generous intake of fruits and green vegetables on this account alone. The value of milk in this connection is also obvious.

The significance of this balance of base against acid in selection of diet is found in a practice that is too common. Realizing that potatoes and rice are both food sources of starch, many people consider that they can vary a meat and potato diet by substitution of rice for the potato and the result will be the same. This may be true from the organic nutrient viewpoint but not from the mineral balance side, for rice yields an acid ash and potatoes a basic ash. Potatoes then tend to balance the acidity of the meat while rice accentuates the acidic content of the diet. This example makes it clear that the effect of minerals

in diet demands attention to selection of foods from that viewpoint alone.

Calcium, magnesium, potassium and sodium are all base-formers while sulfur, chlorine and phosphorus are acid-formers. In nature, however, potassium and sodium are usually combined with chlorine and sulfur as neutral salts. Hence, the acidity or basicity of a food ash is largely determined by the ratio of its calcium and magnesium to its phosphorus. In general, if the calcium and magnesium combined are in excess of the phosphorus in a food the reaction will be basic, and vice-versa. In this fact lies another argument for securing a liberal supply of calcium in our diet, especially since American diets in general tend to be too low in this element.

Other examples might be cited in answer to the question as to why we need minerals in the diet and the significance of balancing the proportions of those we do include. The too great prevalence of anemias emphasizes need for attention to the iron content of the diet. The classic experiments of Marine and Kimball in goitrous districts taught the importance of including in the diet what might appear to be insignificant amounts of iodine. The amazing progress that has been made toward the

elimination of rickets has emphasized the need for definite data regarding the calcium and phosphorus content of diet and the factors which control the absorption and deposit of these elements in the cartilages.

When wheat is milled to make white flour there is removed a part that is much richer in minerals than the part that is left, as shown in table 19.

TABLE 19

Relative mineral content of white and graham flour.

FOODSTUFF	PER CENT OF ASH	PER CENT OF CALCIUM
White flour	0.6	0.020
Graham flour	1.8	0.031
White bread (water)	1.0	0.027
Graham bread	1.3	0.050

Manufacturing refinement then has subjected us to much more danger of mineral deficiency than our ancestors were liable to in the days of whole cereals.

Knowledge of mineral requirement and its importance in selection of diet is of comparatively recent acquisition. Unfortunately, it is still fragmentary. For that reason it will be not amiss to devote another chapter to the review of a few classic experiments in this field.

CHAPTER VII

Some Facts Regarding Mineral Requirements

SOURCES OF CALCIUM

The preceding chapter emphasized the importance of calcium in the diet. In the chapter on the protein requirement, it will be recalled that Sherman said: "The recommendation that family dietaries should wherever possible include a quart of milk a day for every child was aimed primarily to ensure an adequate protein supply. Needless to say, the milk also supplies important amounts of many other substances essential to growth." How did Sherman happen to determine upon a quart as the desirable quantity?

The answer to this question is not the amount of protein in a quart of milk but the value of the milk as a source of calcium. In 1917, Sherman and Gillett made a study of the dietaries of 92 families in New York City with the results below:

	Per cent
Families receiving less than the standard allowance of calcium (0.68 gram)	53.2

	Per cent
Families receiving less than the standard allowance of phosphorus (1.44 gram)	48.9
Families receiving less than the standard allowance of iron (0.015 gram)	41.3

These studies were duplicated by Philips and Howell[1] in 1918, with the results given in table 20. These results justify Sherman's contention that

TABLE 20

Percentage of families receiving less than the standard amounts

ELEMENT	STANDARD	ITALIANS	JEWISH	NEGRO	MISCELLANEOUS	TOTALS
	per cent	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*
Calcium	0.67	51.7	72.2	59.2	25.0	57.3
Phosphorus	1.32	30.0	40.0	60.0	25.0	39.0
Iron	0.015	48.0	50.0	62.9	25.0	51.2

calcium is an element apt to be lacking in American dietaries. Sherman, therefore, set himself the problem of determining the optimum intake of calcium for children, the best source of this element, and the relative value of various natural sources. This work was accomplished with the aid of Miss Hawley and published by Sherman and Hawley in 1922.[2]

[1] Philips and Howell, *Journal of Home Economics*, vol. xii, p. 397, 1920.

[2] Sherman and Hawley, *Journal of Biological Chemistry*, vol. liii, p. 375, 1922.

The results may be summarized very briefly. Working with children from three to thirteen years of age they found quite a wide divergence in the retention of calcium over output per day when the diet was of good character and the calcium provided by 750 grams of milk per day (about 1½ pints). These retentions ranged from 0.15 to, 0.62 gram per day. By increasing the milk intake to 1000 grams (about 1 quart) they obtained better retention, and increase of milk above this amount did not appreciably improve the retention. Sherman and Hawley then set the quart as the optimum amount. In these experiments we have the origin of the "quart" quantity of the slogan cited.

But vegetables also contain calcium. Are they as good a calcium source as milk? To determine this point Sherman and Hawley reduced the children's milk intake to 500 grams, one-half the optimum. The remaining supply of calcium was then made up by vegetables (carrots and spinach) selected in such quantity as to provide a total calcium intake equivalent to that in 1000 grams of milk. The children failed to show as good retention on this as on 1000 grams of milk and no vegetables. The experimenters state their findings as follows:

The writers entertain no doubt as to the desirability of a liberal use of vegetables in the feeding of children, but the vegetables should be used in addition to a liberal allowance of milk and should not be allowed to reduce the amount of milk consumed.

These experiments seem to establish that milk is the best source of calcium, from the viewpoint of utilization, so far known. It may also be noted that this "quart" need not be taken in liquid form to secure good results, and that any known form that provides an intake of 1 gram per day of calcium will serve the same purpose whether consumed as a solid food or in a beverage. The behavior of milk and vegetables also shows that mere quantity of intake of calcium is not the sole determinant in the choice of foods as calcium supply. Quality of source is a factor and protein history is repeating itself in mineral utilization.

Chaney and Blunt, of Chicago, have shown recently that the addition of orange juice to the diet may markedly increase the retention of calcium and by an amount considerably greater than the amount of calcium in the added orange juice itself. The author has been able to show that bananas will accomplish the same effect. Bergeim, of Illinois Medical College, has shown that

milk sugar aids calcium retention while the sugars glucose and sucrose do not have this effect. Flood has also shown that the addition of the mineral acid known as hydrochloric to the milk of normal babies has little power to increase calcium retention but that in the case of rachitic babies such addition is extremely beneficial and makes for greater retention of calcium. Collip has shown that the active principle of the parathyroid gland has a definite influence in regulating the utilization of blood calcium while, as noted before, the history of rickets shows that the use of calcium in bone formation may be controlled to a degree by the amount of phosphorus ingested with the calcium, or by the presence of the vitamin found in cod-liver oil, or created in the body by exposure of the skin to the ultra-violet rays.

Any one of these observations would be significant, but taken together they show how complicated is the problem of mineral metabolism in the human body, and how difficult it is to state a means of food selection that will cover all conditions of the individual consumer. If we do not yet know how to accurately prescribe the protein requirement, still less do we know how to state the calcium requirement. However, since the quart

of milk a day method "works," we may well use it until we have at least learned some better way of accomplishing as good a result. The story of calcium, however, is much more complete today than is our knowledge of the best sources and utilization factors for other mineral elements.

THE IRON PROBLEM

The standard intake for iron has been set at 15 milligrams per man per day, based on practical results, body content and daily elimination. But here again the form of the iron in the food source, the foods eaten with it, and various other factors, all profoundly influence the body's ability to utilize iron. Until recently it was generally held that inorganic iron such as iron oxide or iron rust was of little value for renewing our blood supply of that element. Yet Steenbock and his co-workers in Wisconsin have shown that inorganic iron oxide can be made to serve this purpose admirably if there is fed with the oxide cabbage or extract of cabbage. Helen Mitchell also has shown that iron chloride is better used than iron oxide and maintains that the use of the term "inorganic" is bad, that solubility in the digestive tract is a determinant and not the origin of the iron.

Still more recently Boston investigators have held out the hope that pernicious anemia may ultimately be rendered curable by the use of a diet in which liver is the predominant source of the iron.

One of the most startling discoveries in this field of study has been the announcement by Hart and coworkers that the factor in cabbage, lettuce and liver ashes which enables the body to cure milk induced anemias is copper. Their discovery would link copper as an essential element for construction of hemoglobin and the utilization of iron.

In the case of iron, then, we cannot get away from the fact that to merely prescribe the quantity of iron needed and to purchase foods that contain that amount is not the sole procedure necessary to prevent anemias. Experience has shown that liberal amounts of whole cereals, fruits and green vegetables in the diet will usually maintain a good content of iron in the blood. Meat is a good source of iron but not absolutely essential. Spinach, of all the vegetable sources, has been cited as the best to date. These facts are valuable, but we still have much to learn before we can make our selection of food-iron with scientific certitude.

Meanwhile we can, as in the case of calcium, follow practices that have been successful with others, even if we do not know all the reasons for their efficiency.

THE IODINE PROBLEM

In many regions remote from the sea, cereals, vegetables and drinking water may be so devoid of iodine as to result in a widespread occurrence of

TABLE 21

Iodine in foods (After McClendon)

Amounts expressed in milligrams per metric ton

FOODSTUFF	LOCALITY	IODINE CONTENT	CHARACTER OF LOCALITY
Wheat	Edgecomb, Me.	9.3	Non-goiterous
Wheat	Minnesota	1.0	Goiterous
Oats	Wiscassett, Me.	175.0	Non-goiterous
Oats	Minnesota	10.0	Goiterous

goiter. (See table 21.) Marine and Kimball (1916–1917) took volunteers from among the school children of Akron, Ohio (a goitrous region) and treated over two thousand of them with small doses of sodium iodide, given in the drinking water twice weekly over a period of a month and repeated about twice yearly. Only 5 of these cases showed enlargement during the period while 500

in the same region who did not take the treatment did show enlargement in that period. This classic

TABLE 22*

Distribution of calcium, phosphorus, and iron in some common foodstuffs

FOODSTUFF	GRAMS IN 100 GRAMS OF FOODSTUFF		
	Calcium	Iron	Phosphorus
Beef (all lean (1)	0.007	0.0030	0.218
Eggs	0.067	0.0030	0.180
Milk	0.120	0.0002	0.093
Cheese	0.931	0.0013	0.683
Wheat (entire grain)	0.045	0.0050	0.423
White flour	0.020	0.0010	0.092
Rice polished	0.009	0.0009	0.096
Oatmeal	0.069	0.0038	0.392
Beans (dried)	0.160	0.0070	0.471
Beets	0.029	0.0006	0.039
Cabbage	0.045	0.0011	0.029
Carrots	0.056	0.0006	0.046
Potatoes	0.014	0.0013	0.058
Apples	0.007	0.0003	0.012
Bananas	0.009	0.0006	0.031
Oranges	0.045	0.0002	0.021
Prunes dried	0.054	0.0030	0.105
Almonds	0.239	0.0039	0.465
Peanuts	0.071	0.0020	0.399

* Taken from Sherman's *Chemistry of Food and Nutrition.*

experiment has justified iodine dosage in such regions, and to avoid wastage the administration of the iodine with table salt seems today to offer

the most practical form of its administration. The striking point about this iodine requirement is that a man's body contains only $\frac{1}{2,800,000}$ by weight of this element and yet its omission from the diet means disease and discomfort. Fish and shell fish are good sources of iodine. It is also worthy noting that the work of McClendon and others has shown that fruits and vegetables and milk are all good sources of this element in ordinary regions. Hence, these "protective foods," as McCollum calls them, may do us another good turn by providing our daily iodine supply.

It is not desired by these examples to suggest that the maintenance of an adequate supply of mineral salts by the average purchaser of foods is impossible or even difficult of attainment simply because knowledge is incomplete. On the contrary a very definite step in advance in both practice and theory has been made. As knowledge increases, our skill will undoubtedly improve. Table 22 fittingly closes this discussion as indicating the relative distribution of three of the important mineral elements in common food.

CHAPTER VIII

The Digestibility Factor—What Is Meant by Digestibility?

When are foods indigestible, what are the factors which determine digestibility? The study of nutrients has shown that food consists of combinations of proteins, lipins, carbohydrates and mineral salts, and water. Study of the behavior of our digestive juices (saliva, gastric juice, pancreatic juice and intestinal juice) shows that these contain small amounts of certain chemicals called enzymes. These enzymes, without themselves being consumed, have the power to make water unite with the organic nutrients and as a result the nutrients themselves are split into simpler and simpler substances. Proteins ultimately break down under this process into amino acids. Carbohydrates by the same means ultimately yield mixtures of simple sugars, and fats are broken into fatty acids and glycerine. Since the water is the real agent in the splitting process, the enzymes merely directing the action, we call the process hydrolysis (*hydro* meaning water and

lysis, splitting). Thus the pepsin of the gastric juice brings about the hydrolysis or splitting of proteins. Amylase, the enzyme in saliva, causes the hydrolysis of starch into sugar.

This operation of chemical hydrolysis is of value in the body, for by its means nutrients which are insoluble in the body juices are converted into substances which are soluble, and which will pass through the digestive tract walls and mingle with the blood. Once in the blood they are transported easily to all parts of the body for fuel or building material.

In order that hydrolysis may take place it is evident that the digestive juices with their enzymes must have access to the nutrients. If by ordinary mastication we are unable to break up ordinary food masses, or unless the nutrients are already free and in more or less pure form like sugar and oil, hydrolysis may greatly be hindered and reduced in efficiency, and many of the nutrients that we eat actually fail of digestion and absorption. In this fact lies the explanation of the indigestibility of hay and straw by the human animal, the variation in the availability of nutrients in different sources of the same, the importance of emulsifying fat in order to increase the surface

TABLE 23

Distribution and action of the human digestive enzymes

REGION	DIGESTIVE JUICE	ENZYMES	SUBSTANCE ACTED UPON	EXTENT OF HYDROLYSIS	REMARKS
Mouth	Saliva	Amylase	Starch	To maltose	A sugar
Stomach	Gastric juice	Pepsin	Proteins	To peptone	An amino acid complex simpler than protein
		Rennin	Milk protein	To curds	Prepares milk for digestion
		Lipase	Fats	To acids and glycerine	Splits enough fat to prepare the rest for digestion
Small intestine	Pancreatic juice	Trypsin	Proteins and peptones	To polypeptides	Less complex amino acid combinations than peptone
		Rennin	Milk protein	To curds	Like gastric rennin
		Amylase	Starch	To maltose	Like salivary amylase
		Lipase	Fats	To acids and glycerine	Completes fat digestion
	Intestinal juice	Erepsin	Polypeptids	To amino acids	Completes protein digestion
		The invertases			
		1. Maltase	Maltose	To glucose	Completes starch digestion
		2. Lactase	Milk sugar	To glucose and galactose	Completes milk—sugar digestion
		3. Sucrase	Cane sugar	To glucose and fructose	Completes cane—sugar digestion

exposed to the digestive juices, and the arguments in favor of thorough mastication. It also explains the advantage of cooking in certain instances as a means of softening binding tissues and making mechanical separation more effective. The varying digestive enzmes, their location in the digestive tract and the substances that they hydrolyze are shown in table 23.

If then chemical hydrolysis is unhindered by the composition of the natural food, or other causes, all the proteins we eat will become separated into and absorbed from the small intestine as amino acids. Starch will become glucose; cane sugar, glucose and fructose; milk sugar, glucose and galactose; and fats, acids and glycerine. This will all take place before the food reaches the end of the small intestine, the nutrients will be 100 per cent digested and presumably 100 per cent absorbed into the blood. If for any reason the process is hindered, parts of the undigested nutrients will enter the large intestine. From this region it still is possible for absorption into the blood to take place and, in fact, this region is that in which a large amount of water is so absorbed. If, however, any nutrients have reached this region without digestion they may fail of absorption entirely

and be voided with the feces. It is entirely possible to eat 100 grams of protein and lose over one-half of it through failure of digestion, not because the protein was in itself unhydrolyzable but because the conditions were unfavorable to such chemical action.

This picture of chemical digestion shows why other factors than hydrolysis must be considered in determining the practical "digestibility" of natural foods. The mechanical operation of the digestive tube itself may be such a factor.

MECHANICS OF DIGESTION

Due to the work of Cannon, of Harvard, we now have an excellent knowledge of the mechanics of digestion and that knowledge has been much furthered by Carlson and investigators of the University of Chicago in this field. Cannon discovered that if foods be impregnated with salts of bismuth they became impervious to the x-rays, just as nails or bones are impervious. By a practical development of this observation he was able to study both experimental animals and man with the aid of the x-ray and learn how the alimentary musculature functions; what factors stimulate it to greater activity and what inhibits

its action. His studies demonstrated, among other things, that our system needs a certain amount of indigestible matter or roughage to keep our churning muscles in tone. Without this they become stale, just as our body muscles lose tone from lack of exercise. Food is delayed in transit and constipation results. With such delay the bacteria that are in our tract have a chance to act on the normal digestion products and break them up still further, forming poisons which we absorb into the blood and producing the headaches and disturbances that follow this invasion.

This result is a part of the basis for objection to too great refinement in the treatment of natural foodstuffs. To remove all the indigestible matter from it would do more harm than good. It also demonstrates the need for spinach, lettuce, fruits, and nuts, other than for their calories or minerals, namely on account of their roughage and laxative propensities.

THE TIME FACTOR AND THE ACTION OF FOODS ON SECRETION OF JUICES

Another series of studies of digestion have been made by Rehfuss, Hawk, and co-workers. These

TABLE 24*

Time in hours for various types of foods to pass through stomach together with their effect on the secretion of gastric juice

ARTICLES OF DIET 100 GRAM PORTIONS UNLESS OTHERWISE STATED	NUMBER OF OBSERVATIONS	EVACUATION TIME IN HOURS			NUMBER OF OBSERVATIONS	HIGHEST TOTAL ACIDITY IN CUBIC CENTIMETERS OF N/10 ALKALI TO NEUTRALISE 100 CC. JUICE
		Rapid	Slow	Average		
Milk (cow) 400 cc.	50	—	—	2.30	50	100.00
Fruits	68	1.35	2.20	2.00	68	90.00
Vegetables prepared in different ways	124	2.00	2.30	2.15	124	75.00
Sugars and candies	28	—	—	2.05	28	70.00
Puddings	23	—	—	2.20	23	90.00
Pies	29	—	—	2.30	29	90.00
Ices	4	—	—	2.35	4	65.00
Ice cream	7	—	—	3.15	7	105.00
Bread and cereals	75	—	—	2.40	75	80.00
Egg and egg combinations	90	2.15	3.15	2.40	90	80.00
Fish	75	—	—	2.50	75	130.00
Beef and beef products	25	2.35	3.25	3.00	25	120.00
Cakes	29	—	—	3.00	29	90.00
Chicken	20	2.45	3.45	3.15	20	125.00
Lamb and lamb products	14	2.30	3.20	3.00	14	135.00
Veal	7	—	—	2.50	7	140.00
Pork and pork products	31	2.45	3.40	3.15	31	120.00
Turkey	2	3.00	3.45	3.30	2	140.00

* Taken from Hawk's and Bergeim's *Practical Physiological Chemistry*, ninth edition, published by Blakiston.

were based on the use of the stomach and duodenal tubes developed by Rehfuss. The coöperating subjects in these tests first were given weighed amounts of selected foodstuffs. They then swallowed the tube and its position in the stomach or duodenum was fixed by the aid of the x-ray and fluoroscope. By means of these tubes samples could be withdrawn from time to time and studied analytically. Two phases of the recorded observations are of particular interest: (1) those which told of the length of time required for different kinds of food to pass through the stomach; (2) the effect of each type of foodstuff on the secretion and composition of gastric juice. Table 24 gives in condensed form some of these observations.

In studying this table certain facts stand out clearly. First, the experimenters found that people differ markedly in the rate at which they evacuate the same food. Roughly, humanity can be classed into rapid stomach types and slow stomach types, the difference being as much as thirty minutes to an hour in certain cases. Practically, this would indicate that the slower type must allow more time than the other between meals or reduce the quantities to avoid rear-end

collisions. Second, it will be observed that foods rich in proteins or fat require much longer digestion time than the foods which are rich in starch or sugar; cereals, fruits, and vegetables all passing through the stomach very rapidly in contrast. Finally, since the gastric juice contains hydrochloric acid, the more the secretion the higher the acidity. Furthermore, this acid is necessary to properly digest the proteins. Since candies and starches tend to reduce acidity, while proteins increase it, a diet too high in starch and sugar may prevent digestion of the protein. Again, since the acid is necessary to destroy certain fermentative organisms, too high a starch and sugar diet not only permits the organisms to live but allows them to ferment the sugars with actual production of alcohol and other fermentative poisons. In fact, it is possible to produce the effects of alcoholic intoxication by eating too much sugar.

THE RELATION OF THE BACTERIA OF THE DIGESTIVE TRACT TO DIGESTIBILITY

The last observation suggests another field of study that has only begun to be investigated. The character of the bacterial flora of our digestive tract may make it an important controlling element

in determining the utilization of foods that we eat. This bacterial population, ever present, can be rapidly changed in character. It was Metchnikoff who first showed that if we develop the sour milk bacterium in our intestines, this unicellular organism can efficiently reduce the population of bacteria that split our proteins into toxic substances. He showed that this change can be accomplished in two ways; either by eating cultures of these bacteria or by eating large quantities of the milk sugar on which they thrive. Sour milk contains both the organisms and the sugar, and the various sour-milk preparations that are now on the market as well as butter milk owe their popularity to the teachings of Metchnikoff.

We have made much progress since Metchnikoff pointed the way. We have found another bacterium that has the same powers (acidophilus), and which is less difficult to grow. We have also learned other ways to control the bacterial population but we have still much to learn of the effect of food mixtures on this bacterial flora and of the digestibility of such mixtures from this viewpoint alone. Take the observation of Bergeim, noted in a previous chapter, in regard to the power of lactose to increase the absorption and utilization

of calcium. This lactose of milk sugar may accomplish its end by developing the sour-milk bacteria, which in turn tend to increase the acidity of the region where calcium is absorbed. In an acid medium calcium forms salts that are more soluble, and hence more readily absorbed. The function of the lactose, or milk sugar, may be an indirect result of its effect on the intestinal bacteria and not because of its effect on calcium per se.

COEFFICIENT OF DIGESTION

Practically we have not determined the digestibility of any food mixture by proving that it contains chemically hydrolyzable components. Neither can we know the digestibility of a mixture of foods by determining the digestibility of the single components of the mixture, for in combination they may influence one another. Our only practical method of ascertaining such data is by feeding individual foods and mixtures to human beings of different ages and types and measuring the amounts that are actually absorbed. This is called taking the *coefficient of digestion.* Briefly, it consists of the following operation: Feed a given quantity of the food (*A* grams) after first

giving a colored substance that will be detectable in the feces. When this mark appears in the feces collect them until the second mark appears (given after feeding A grams of food). Analyze these feces for the food. Assume we recover B grams of it. Then $\frac{A - B}{A}$ is the coefficient of digestion. For example, suppose we fed 100 grams of green peas and recovered 40 grams in the feces. The coefficient of digestion would then be $\frac{100 - 40}{100}$ or 60. We would then say that green peas for that individual were 60 per cent digestible, assuming that the 60 grams unrecovered has been absorbed.

Data of this kind is slow of acquisition but until it has been obtained for many different types of individuals, and for combinations of foods as well as for single foods, we shall lack definite practical data on the subject. It was for a long time asserted that raw starch was undigestible, until Langworthy by this method proved that raw starch eaten in the form of a frozen cream had actually a coefficient of digestion of about 90. Since then we have not been at all sure that cooking was necessary to permit the digestion of certain forms of starch.

SUMMARY

Even this brief review of the subject will make it clear that there are many factors that must be considered if we wish to avoid "indigestion." Chewing becomes an important factor, for by it we permit the juices to get at the nutrients and without such mastication the foods may merely pass through the tract without absorption or, worse yet, provide material for bacteria to attack and split into poisons. Exercise also becomes a factor, for our intestinal muscles are kept in tone in proportion as our voluntary muscles maintain their status of health. The eating of too high a carbohydrate diet may lower the tone of the musculature, reduce acidity, permit the development of fermentative bacteria and thus impair the whole machinery. Eating foods that are devoid of sufficient roughage may so reduce the muscular tone that the passage of foods is delayed, constipation developed, and bacteria allowed to do their deadly work on the retained food mass. The abundance of cathartics that are advertised is sufficient evidence that we are much too prone to invite digestive disturbance by lack of roughage in the diet and by lack of care as to amounts eaten

and exercise taken. It is safe to assert that in very few instances are any food mixtures in themselves harmful to digestion. The trouble arises with our use of these mixtures and the neglect of the rules for maintaining an efficient machinery.

PART II

VITAMIN REQUIREMENTS

INTRODUCTION TO PART II

The preceding eight chapters have aimed to make clear a point that modern day advertising has sometimes obscured, namely, that the attainment of a good nutrition involves attention to many contributing factors and not to the use of any one particular food, regardless of the merits of that particular article. Within the past fifteen years new nutritional factors (the vitamins) have been discovered and these have provided attractive material for the advertising copy writer. "Our food contains vitamins" is used to imply "eat and be healthy."

It is true that the presence of vitamins in the diet is essential to health, but their presence is no more imperative than calories, nutrient quality, digestibility, etc. Their discovery has not made unnecessary attention to the factors described in Chapters I to VIII, but merely has defined another series of substances whose inclusion in diet must be assured *in addition to these other factors.*

In the succeeding chapters it is proposed to record in some detail what we have learned in

the past fifteen years about the vitamins. The expansion of this data in considerable detail is warranted, not because they are more important factors than the preceding, but because our knowledge is of much more recent origin and not so well grounded in experience.

CHAPTER IX

WHO DISCOVERED VITAMINS?

In 1898 attention was directed by Chittenden toward the value of protein in the diet, and at that time he began to question the tendency of the American people to overeat of this particular nutrient. Methods of accurately measuring human requirements for this protein were developed and such studies led to those of F. Gowland Hopkins in England and to those of Osborne and Mendel of New Haven; studies which became productive of unexpected results.

Experiments were made to determine the quality of certain proteins. To measure this, both groups found it desirable to use small animals and adopted the white rat for this purpose. It will be obvious that in order to show how a given protein could be improved by the addition of amino acids or other proteins, the rest of the diet must meet all the nutritional requirements except that of protein. These investigators were then forced to develop what we call today *basal diets* for their animals, which should be complete not only in,

all factors except the one to be tested but which of themselves should be composed only of known ingredients. Table 25 illustrates the nature of such basal diets developed by Osborne and Mendel. Such a diet provided 4.3 calories per gram of food-mixture and it was found by observation of the white rats that these animals would eat enough of

TABLE 25

A typical Osborne and Mendel diet for study of protein quality

DIET	PER CENT
Protein requirement met by purified milk casein.........	18
Calorie requirement met by purified corn starch.........	58
Calorie and fat requirement supplemented by purified lard.	14
Roughage requirement met by agar-agar...............	5
Mineral requirement met by a mixture of salts such as was yielded by the ash of milk.........................	5
Total..	100

this mixture per day to meet their calorie requirements. The diet represented all the nutrient factors known at the time and which would be adequate for the normal growth of the rat.

When Hopkins used a similar diet in his experiments, he found it impossible to keep his animals alive more than for a few months. He then went farther and found that if to this diet he added a few

cubic centimeters of milk per day per rat the diet became adequate. This small amount of milk thus contributed some thing, or things, evidently small in amount but essential to life. It also made no difference whether the milk was fresh or dried. The alcohol-soluble fraction of dried milk and of certain vegetables showed the same growth-promoting power and the ash or mineral part of milk failed to do so.

Hence in an address published in the *Annalist*, in 1906, Hopkins made the following statement:

> No animal can live upon a mixture of pure protein, fat, and carbohydrate and even when the necessary inorganic material is carefully supplied, the animal still cannot flourish. The animal body is adjusted to live either upon plant tissues or other animals and these contain countless substances other than the proteins, carbohydrates and fats.

This was the first definite statement recognizing the presence in foodstuffs of factors other than nutrients, calories, and digestibility necessary to a complete diet and has brought to Hopkins general recognition as being the first to recognize the need in human diet of what we today call vitamins.

The confirmation of this viewpoint by Osborne and Mendel and their discovery of the presence of

such factors in "protein-free milk" is one of the classics of vitamin research.

Like most important *new* discoveries the actual development of the vitamin hypothesis had many points of origin. The development of the term vitamin itself came as a sequence to studies inaugurated long before Hopkins' feeding work with rats. In the Orient there was a disease of frequent occurrence known as beri-beri. This disease became annoyingly prevalent in the Japanese navy. One of the naval surgeons, Takaki, came to the conclusion that the fish and rice diet of the sailors was contributory and proved that the scourge was of dietary origin by changing the ration to include a more varied diet. This empirical result solved the problem from the practical viewpoint but did not explain the origin of the disease or the method of cure in terms of causal or preventive factors. Much greater scientific progress to this end developed at the experimental station maintained by the Dutch in Java. Here, in hospitals where beri-beri cases were studied, an extremely important discovery was made by C. Eijkman and further developed by Grijns. Eijkman discovered that beri-beri was reproducible in fowls by restricting them to a diet of polished

rice. He missed at the time the actual significance of his experiments but his demonstration that human beri-beri could be simulated in birds was of incalculable importance, for that discovery made possible the scientific study of the disease and its origin.

Utilization of Eijkman's discovery was made by two Englishmen (Fraser and Stanton) which led to the proof that rice polishings contain a substance curative for the disease and that this substance was extractable from the polishings by alcohol. The attempt of Schaumann in Germany to demonstrate that the curative substance was necessary to phosphorus metabolism failed to prove this point, but did result in the discovery that the unknown factor existed in rich concentration in yeast. The work of the United States Army laboratory in the Philippines, and many other contributory investigations, all owed their impetus and development to the primary discovery of Eijkman.

Three groups of workers finally concentrated on the chemical identification of the factor. Suzuki, Shimmamura, and Odake in Japan obtained a curative fraction from rice polishings to which they gave the name *oryzanin*. Edie and

Simpson announced the separation of a fraction which they called *torulin*. In Hopkins' laboratory a Polish chemist by the name of Casimir Funk laboriously fractioned large quantities of rice polishings, and later yeast, and obtained a very small yield of what appeared at the time to be crystals of chemical purity, possessing the element nitrogen in basic combination. These crystals, in small doses, cured beri-beri.

Believing that he had isolated the true preventive substance, and believing it to be a nitrogenous base, Funk classified his compound in the chemical field as an *amine*, the chemist's name for such nitrogenous bases. To distinguish it from other amines he prefixed the term "vita" or life. Thus the origin of the term now in common use.

The chemical nature of Funk's crystals has never been satisfactorily explained. Later study of them seemed to prove that they were largely composed of nicotinic acid but whether this was true or not is still an open question. At any rate it is now held that they were not pure vitamine. The name, vitamine, however, retained its hold. It had marked superiority in brevity to McCollum's phrase "unidentified dietary factor water soluble B." Its use, however, rather irked the

conscientious chemist, for it was undemonstrated whether this vitamin was an *amine* in structure. In fact, it is still unknown whether the beri-beri factor is an amine or not, and it is definitely certain that some of the factors we now put in this group are not amines. On account of this uncertainty, J. C. Drummond suggested some years ago that we solve the difficulty by dropping the terminal *e* from the word and call these factors *vitamins*. This spelling change has salved the scientific conscience and retained the advantage of a single name. This name now is applied, therefore, to at least five substances including the substance postulated by Hopkins as present in milk, the substance found by McCollum in butter and egg fat, the substance found by Holst and Fröhlich in fruits, the substance demonstrated in cod-liver oil by various investigators, and the component described by Evans as present in wheat germ oil.

The story of the discovery of the vitamins, the part played by the different investigators, the relative contributions of each are all matters of keen historical interest. Unfortunately, to relate them with proper credit to each contributor would require far more space than is possible in this text.

Also, it is possible today to read this story in the writings of the principal contributors. A bibliography is appended for the benefit of those interested in this phase of the subject, and we will confine our treatment of vitamins in this book to what we have learned of their significance in nutrition.

CHAPTER X

What Are Vitamins?

A brief but comprehensive definition of a vitamin is as follows: "It is a substance of relatively simple chemical composition, present in various natural foodstuffs in differing concentration, and its continued absence from the diet results sooner or later in a definite pathological or diseased condition, the condition enabling us to state definitely what vitamin is lacking."

This definition is preferred because it makes definite the idea that vitamins are essential to our diet, not accessory. It also avoids the implication that vitamins are stimulants instead of food factors. If you lack a vitamin in your diet you suffer a certain kind of illness. If you have it, you will remain normal. If you get more than your requirement you will not, so far as we know today, ever become conscious of its presence for aside from insuring normality it contributes no "pep" or stimulus of any sort.[1]

[1] Certain Japanese chemists who isolated from cod-liver oil a compound which they believed to be vitamin A reported that it was

The chemical composition of a vitamin[2] is not known as yet, but since several are readily diffusible through membranes of known porosity we are sure that the vitamin molecule cannot be very large, and that they must be relatively simple organic compounds. The above definition also enables us to support Mendel's suggestion that we buy our vitamins in the markets and grocery stores and not in the drug store.

WHAT DO WE KNOW OF THE DIFFERENT KINDS?

Vitamin A

This is the name given to the vitamin first demonstrated by McCollum and Davis to be present in butter-fat and egg-fat, and later to be widely distributed in green vegetables and especially concentrated in cod-liver oil. Its omission from the diet results in cessation of growth, a dry-

possible to give enough of this substance to produce death. The purity of their product has been questioned by Drummond and the suggestion made that the evil effects of overdosage might be due to impurity. With this possible exception we have today no evidence of harmful effects from taking too much of any vitamin.

[2] Very recently Jansen and Donath have announced the isolation of a crystalline anti-neuritic vitamin to which they give the chemical formula $C_5H_{10}ON_2$. Confirmation of this work will substantiate the view that a vitamin molecule is relatively simple in composition.

ing-up of the tear glands and subsequent development of an eye affection known as xerophthalmia or kerato-malacia, together with development of pus sacs in various body glands and a general lowering of our resistance to agents of infection. Because of the disease its absence creates, and its presence prevents, it is called the anti-xerophthalmic or anti-ophthalmic vitamin. McCollum labeled it "unidentified dietary factor fat-soluble A," because apparently it is soluble in fat, and in animal sources of the vitamin exists mainly in such solution.

Vitamin B

This is the vitamin that Funk believed he had isolated from rice polishings, and which Jansen and Donath now claim to have isolated in true form. It is one of the factors that was in Hopkins' milk, and Osborne and Mendel's protein-free milk. Its richest known source is yeast, but it is widely distributed in whole cereals, vegetables, fruits, nuts and in fact in most foods except meats and fish. Removal of the grain coats eliminates much of it from cereals, hence highly milled products such as white flour and polished rice contain very little.

The absence of this vitamin from the diet results in cessation of growth, the growth ceasing relatively quickly following the deprivation of the factor, for unlike vitamin A, the body cannot store this vitamin and its removal from diet results in fairly rapid evidence of the absence. Its absence also results in a multiple inflammation of the nerves which is called "polyneuritis" and this inflammation is succeeded by loss of control of certain muscular activities, particularly paralysis of the posterior extremities. This polyneuritis is one of the manifestations of the disease known as beri-beri. Its relation to beri-beri has given it the name of the anti-beri-beri vitamin or the anti-neuritic vitamin.

Evidence is accumulating steadily that what we have called vitamin B is a complex of several vitamin factors rather than a single substance. Smith and Hendricks first presented definite evidence of there being two kinds of vitamin B and Goldberger shortly after that yeast contains two water-soluble vitamins, one curative of beri-beri and the other curative of the disease called pellagra. He suggested for the latter the name pellagra-preventive vitamin or P-P. Since this announcement work in America

(notably by Hauge and Carrick, Salmon, Axtmayer, Williams, R. R.) and in England (notably by Peters, Chick and Roscoe, Drummond) as well as data contributed by French workers (Randouin and LeCoq) has gone far to support the view that what we have called vitamin B must be admitted to be a complex of at least two different vitamins and probably more. In the author's laboratory Williams and Waterman have recently produced evidence that yeast and whole wheat contain at least three vitamin B factors two of which (the antineuritic and P-P of Goldberger) are essential to normal rat growth and two (the antineuritic and a new factor not P-P) essential to pigeon weight maintenance. At the moment of writing much of the above data is just beginning to appear in the scientific press but enough has already been presented to show that our previous tests for vitamin B will need revision and each factor will have to be assayed to establish its proportion. Already progress in this direction is developing. Wheat embryo and corn have been shown to be much richer in the antineuritic factor than in the pellagra-preventive factor and it has been demonstrated that the content of these two factors in yeast is markedly

influenced by the medium on which the yeast is grown. The discovery is too recent to attempt here a detailed account of its significance. Unlike vitamin A both vitamin B components are readily soluble in water, hence McCollum named vitamin B the "unidentified dietary factor water-soluble B."

Vitamin C

The knowledge that human scurvy could be prevented by liberal use of lemons or raw vegetables and fruits was noted by John Lind in 1700. It was, however, as recently as 1912 that Holst and Fröhlich explained the potency of these fruits and vegetables as due to a vitamin. Its absence from the diet quickly results in hemorrhagic lesions in the blood vessels, loosening of teeth and defects in lime deposition in the bones, all these phenomena constituting the disease called scurvy. On that account this vitamin is known as the antiscorbutic vitamin. Like vitamin B it is readily soluble in water and in McCollum's nomenclature became "unidentified dietary factor water-soluble C."

Zilva, of England, has probably contributed more to our knowledge of the chemistry of this

factor than any one other investigator, and his studies have shown that its molecule must be relatively small in size for it readily passes through membranes by diffusion, and the size of the pores in these membranes indicates that it cannot be much larger than a molecule of glucose. Bezssonov and Randouin of France have very recently suggested that vitamin C is a complex, like vitamin B, of at least two factors but their work as yet lacks confirmation.

Vitamin D

Cod-liver oil was found to be very rich in vitamin A and at one time it was thought that its power to prevent rickets was due to this vitamin. Ultimately this was shown to be due to the presence of a vitamin other than A. For that reason some writers speak of the antirachitic vitamin of cod-liver oil as one of the two A vitamins. This usage is confusing and in America we have held it better to put it in its alphabetical place in order of demonstration and call it vitamin D. McCollum was the first to produce satisfactory evidence that cod-liver oil contained a vitamin that was not vitamin A, though many other students contributed to show that it was not A which was

protective against rickets. Unlike the other vitamins, its presence in the diet is not absolutely essential, for if we expose the skin to the rays of the ultra-violet light we can apparently create this vitamin within our bodies or at least produce something that will function just as well. This fact probably explains why nature has been so stingy with her distribution of this vitamin in foods. To date, fish oils are all known to be rich in the factor and egg yolk also contains it. Milk has it in very small amount. No other foods are known to contain it in any abundance but since exposing foods to ultra-violet rays creates the substance in these foods, it follows that vegetables will have more or less of the factor since they are more or less subject to the direct rays of the sun.

The absence of this factor from the diet or body means failure to utilize properly the calcium in the production of bone. This failure in children is described under the term rickets. Adults, however, can suffer from omission of this vitamin for if it is not present to permit the adult to utilize his lime he will draw that element from the bones and a porosity will develop. Its function and method of action is then a very significant part of the problem of calcium utilization. Like vitamin

A, vitamin D is found in that part of the natural fat which will not form soap. In brief if we saponify a fat rich in vitamin A or vitamin D, and remove the soap the vitamines are left in the non-saponifiable fraction. Such fractions contain a class of lipins known as sterols. At one time it was believed that vitamin D was a form of cholesterol. Recent advices suggest that it is a sterol associated with cholesterol but of slightly different chemical composition. The name "ergosterol" has been used by English workers to designate this particular form. Rosenheim and Webster in England being the first to prove that irradiated ergosterol is a potent antirachitic in doses as low as $\frac{1}{10,000}$ mgm. per rat per day.

Vitamin E

In 1920 Evans and Bishop first postulated the presence of this factor in wheat germ and in lettuce. They had observed that when rats were fed on a diet supposedly complete in all known dietary factors, including liberal amounts of vitamins A, B, C, and D, the males in course of time became infertile and the females unable to produce normal litters. Small additions of wheat germ, lettuce or meat, prevented this condition. Fur-

ther study of this problem convinced them that these foodstuffs contain a vitamin of a different nature and function than those already listed and which is necessary to fertility. They called it vitamin E or the anti-sterility vitamin. It apparently belongs to the class in which vitamin A and vitamin D are placed, for it is associated with the unsaponifiable fat part of the foods. Its chemical nature is now under active investigation by California workers but little is known of it to date.

Other Vitamins

The preceding five vitamins are those that seem to be adequately demonstrated as affecting animal nutrition to date. There is no evidence that others do *not* exist. In fact, Barnett Sure, of Arkansas, is very positive that there is a factor quite distinct from vitamin E that is necessary to milk formation and has listed a series of foods that seem to possess such a substance. Evans has also recently reported the presence in the saponifiable part of lard of a factor which he tentatively calls vitamin F. The fractionation of vitamin B into at least 3 factors, the above-mentioned discoveries, now raises both the probability of extension of the list and a problem in nomenclature.

DO PLANTS REQUIRE VITAMINS?

It seems strange that all the vitamins so far discovered are, with the possible exception of vitamin D, obtainable by animals through ingesting vegetable food. We know today, for example, that while butter and milk contain vitamins the cow will not produce vitamin-rich milk unless her diet contains vitamins, and if cows be placed on winter feed their milk rapidly becomes much changed in vitamin content as the cereals increase and green fodder becomes reduced. Cod-liver oil apparently owes its content of vitamins A and D to the marine plants the fish eats and not to construction by the fish. This fact, that all of these vitamins are of vegetable origin, certainly suggests strongly that they have some function in the plants where they originate. We have, however, no evidence of what the vitamins do in the plant. We do, however, have definite evidence in the case of bacteria and yeasts that their growth and development requires the presence of certain substances which are at least vitamin-like in function. Among these is a substance first postulated by Wildier, of Belgium, and claimed by him to be essential to the growth of yeast. Wildier called this sub-

stance "bios." At one time bios and vitamin B were believed to be identical, but we now know substances exist that exert the "bios effect" on yeast which will not prevent polyneuritis or cure pellagra.

At this point it is desired to suggest that the need of plants for vitamin substances is a phase of plant physiology that is quite in its infancy, and that from the viewpoint of human nutrition our concern is primarily with vitamins that can be shown to affect human nutrition. It may well be, however, that study of plant "bioses" will contribute much to our understanding and appreciation of the structure and physiological behavior of what we now call vitamins.

CHAPTER XI

How Is the Vitamin Value of a Food Determined?

The principle on which vitamin testing is based today, has been suggested by the definitions of the preceding chapter. Evidently the diet must be complete in all known factors except the vitamin for which we are testing, otherwise the behavior of the animals may be due to multiple causes instead of to absence of a single factor. Equally obviously, the fact of vitamin absence or presence rests not on growth results alone but on demonstration of the deficiency disease induced by lack of the vitamin.

Simple as are these rules, their development into a quantitative method for determining vitamin kind and quantity is still in process of evolution. We cannot take maintenance of normal growth as evidence of completeness of diet for we cannot absolutely control heredity and individual variation in test animals. We also have found that results obtained with one kind of animal are not necessarily transferable to another species.

Rats, for example, cannot be used to test for vitamin C, for exclusion of this factor from their diet fails to result in scurvy. It has been developed gradually that some of the vitamins can be stored by animals and thus protect them over a period of dietary deprivation. Such animals are obviously unreliable as test animals for that particular vitamin, unless a dietary régime previous to the test has eliminated completely the stored factor. Again, the activity of vitamins is variable owing to its control by such conditions as variation in temperature, duration of heating, oxidation, acidity, and alkalinity. A raw food may show a food content of a vitamin and the same food lose all its vitamin by manipulation of the cook before it reaches the table. Worst of all, the earlier measurements of vitamin content were made before many of the factors were known and there is proof that present tests may require further revision as new facts emerge from continued experimentation.

In spite of all these difficulties, however, progress is being made, and the nature of the means by which we are learning where to pick our vitamins may be best illustrated by specific instances and descriptions of test methods but with full apprecia-

tion of the fact that these very tests may reveal ony part of the truth and may require further modification with time and scientific progress. In presenting the following methods no claim is made to originality for the systems used. Neither is it possible to make suitable acknowledgment of the origin of all the variations that have been introduced into the methods of today, for they come from the efforts of many workers in diverse fields of vitamin research.

In the development of the methods now in use in the author's own laboratory, which will be here described, suggestions from the work of H. C. Sherman and his collaborators have been the fundamental basis. The use of the pigeons in vitamin B testing has been the result of studies by our associate in vitamin research, R. R. Williams. The work of many others, however, has been contributory; to mention only that of Osborne and Mendel, E. V. McCollum, H. Steenbock, Alfred Hess, A. D. Emmett, J. C. Drummond, and Casimir Funk, all pioneers in this field. This list is very partial for many others deserve credit for contributions of data on which methods of today are based.

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The white rat is used extensively in all labora-

tories as a test animal for measuring vitamins A, B, D and E content. For vitamin C tests, the guinea pig is used almost exclusively. In testing for vitamins B and D, however, the use of birds is also in common practice, such use being largely confined to chicks and pigeons. Apparently the need for vitamins is shared by most of the members of the animal kingdom, though individual differences are inevitable and hence the selection of test animals has been guided largely by questions of convenience of manipulation and cost. The white rat has been extraordinarily well standardized by intensive breeding. It is omnivorous, endures captivity well, and has a relatively short life cycle (three years of a rat's life corresponding roughly to ninety years of human life). Statistical studies by the Wistar Institute of Philadelphia have also given us reliable data on which to base predictions as to behavior and growth rate, etc.

The advantage of this small animal is well illustrated by the early experiments of Hart and McCollum. These authors made a study of the reaction of heifers to oats, corn, and wheat. The response of the heifers required two years on the diets and it was only when McCollum turned to the smaller animals that the real differences be-

tween these cereals became possible of demonstration.

A METHOD FOR MEASURING VITAMIN A CONTENT[1]

The most important discovery from the testing viewpoint which concerns this vitamin was that it can be stored in the rat body and utilized in periods of dietary deficiency. Sherman and Boynton obtained a very satisfactory demonstration of this fact by using the organs and tissues of rats as sources of this vitamin in feeding experiments. They found that if adipose tissue and skin be ignored, about 90 per cent of the vitamin A stored in the body of a rat will be found in the liver of the animal; the rest about equally distributed between the muscles, blood, kidney, and lungs. They also found:

> Moderate differences in the vitamin A content of food, such as are well within the range of variation likely to be encountered in human experience, resulted in large differences in concentration of this vitamin in the liver, and distinct differences in the amount of it found in lung tissue.

These results showed that to detect small quantities of vitamin A, rats must first be freed of the

[1] After Sherman.

stored vitamin. We have for some years bred out stock animals on the Sherman basal diet No. 13 which consists of two third ground whole wheat, one third whole milk powder (with us, "Klim") plus one part of common salt (NaCl) per hundred parts by weight of the wheat-milk mixture. This diet produces normal growth and reproduction and has been in constant use for at least ten years. It is easily compounded and made uniform.

When a litter of rats from such stock is taken from the mother, at thirty days of age, and placed in separate cages (each cage with a raised wire mesh bottom and the meshes of sufficient size to allow the feces to drop through out of reach of the animals), and fed on a diet complete in all factors except vitamin A they will in from thirty to thirty-five days become entirely freed of vitamin A. We use for this purpose a modification of Sherman's diet No. 379:

Composition of diet No. 379

	Per cent
Purified milk casein	18
Corn starch	72
Dried yeast	5
Osborne and Mendel salts	4
Sodium chloride	1

Osborne and Mendel salt mixture

	Grams
$CaCO_3$	134.8
$MgCO_3$	24.2
Na_2CO_3	34.2
K_2CO_3	141.3
H_3PO_4	103.2
HCl	53.4
H_2SO_4	9.2
Citric acid: H_2O	111.1
Iron citrate	63.4
KI	0.020
$MnSO_4$	0.079
NaF	0.248
$K_2Al_2(SO_4)_2$	0.245

N.B. To make the salt mixture the acids are first mixed and the carbonates and citrates added. The traces of KI, etc., are then added as solutions of known concentration. The entire mixture is then evaporated to a dryness in a current of air at 90° to 100°C. and the residue ground to a fine powder. This mixture supplies the mineral elements needed by the rat.

The only modification we have made in this diet is to feed the dried yeast separately. Our experience has agreed with that of Osborne and Mendel in finding this procedure a better insurance of adequate supply of vitamin B complex. We purify our casein by extracting for several hours in flasks fitted with reflux condensers, using 95 per cent alcohol as the extractant.

After the thirty-day-old rats are placed on this diet, weights are taken every five days and the food

intake is measured. If they eat normally the weight curve will begin to decline about the thirtieth to the thirty-fifth day. If this decline is confirmed by the result on the next weighing day, we can safely assume that the rats are now free of stored vitamin A. Now the actual test begins. Several rats are kept on diet No. 379 until death ensues, to make sure that the diet is really vitamin A free. These are the controls. To the others we furnish each day a weighed portion of the food under test, plus diet No. 379 and water *ad libitum*. By using several animals and various weights of food under test, the rats will (if the food contains vitamin A) now begin to show weight gains which are proportional directly to the amount of vitamin A in the food. It is imperative, however, that the intake of diet No. 379 be also carefully noted. If for any reason they fail to eat their quota of this basal diet the weight change obviously is not a result of the vitamin lack alone.

The statistics given of some typical experiments will better illustrate the nature of the animal responses, and how these are converted into evidence of vitamin values. The standard of comparison may be selected arbitrarily. We have adopted for our standard the amount of vitamin in 20

milligrams of good butter. This amount per rat per day as the sole source of vitamin A, will produce about 25 grams gain in body weight in sixty days or approximately 3 grams gain per rat per week. This unit was suggested by Sherman and has been adopted by the United States Pharma-

TABLE 26

Some vitamin A test results from the author's laboratory

FOODSTUFF TESTED	AMOUNT NECESSARY TO PRODUCE 25 GRAMS GAIN IN SIXTY DAYS	RELATIVE RICHNESS AS COMPARED WITH BUTTER; 20 MILLIGRAMS BUTTER CONSIDERED AS UNIT
	milligrams	
Canned peaches	500	$\frac{1}{25}$
Raw spinach	18	$1\frac{1}{9}$
Ripe raw bananas	400–500	$\frac{1}{20}-\frac{1}{25}$
Raw green peas	500	$\frac{1}{25}$
Stove cooked green peas	500	$\frac{1}{25}$
Canned peas	500	$\frac{1}{25}$

copoeia. An amount of food that will produce an equivalent result can have its content stated in this unit, and be thus compared directly with butter or other sources of vitamin A. Some of our own results by this test method are given to illustrate such comparisons. (See table 26.) These results illustrate not only the method but also show that vitamin A content suffers very little from cooking operations.

We believe that this method is adequate for quantitative estimation of vitamin A content in such foods as contain it in sufficient richness to be used. If a food is very poor in the vitamin, it may be necessary for the animal to eat so much of it to secure the unit quantity as to make the test fail, for obviously the animal must eat an adequate amount of the basal diet to secure all the other factors, and if in addition it is desired for it to eat a large quantity of another food we reach an impasse which vitiates the whole experiment.

This method has been criticized recently by Steenbock and by Drummond on the plea that the basal diet used does not adequately provide for a supply of vitamin D. Since cod-liver oil which carries this factor is also rich in vitamin A it cannot be added. Hess and Steenbock, however, have shown recently that if we expose either the experimental animal or its food to the ultraviolet rays this treatment will supply adequate vitamin D. Such an additional treatment has been used by us, but with the method given above we found the results were not changed. We believe that animals bred on diet No. 13 receive enough vitamin D from the milk to last them through the experiment, if the rate of gain is

restricted to 25 grams in sixty days, and our tests confirm this viewpoint. It is not difficult, however, to use irradiated basal diet and thus avoid all possible doubt.

We have outlined our method in some detail in order that the precautions necessary to accurate work might be realized. We have described the method devised by Sherman not because it is the only method possible, but because we have found it very satisfactory in practice. Some investigators object to the use of dry powders, such as diet No. 379, because it is difficult to measure accurately the daily intake, animals being prone to scatter this sort of food. Osborne and Mendel, for example, prefer a paste form of diet to avoid this difficulty. The following vitamin A free diet devised by them may be used in place of No. 379:

	Per cent
Purified casein	18
Corn starch	48
Lard	30
Salts	4

0.3 gram dried yeast fed separately per rat per day.

Such a mixture can be molded into a paste, because of the lard content, without danger of scat-

tering. Hawk recommends the following modification for the same reasons:

	Per cent
Purified casein	20
Starch	56
Lard	15
Salts	4
Dried yeast	5

Variants will be found in the practice of almost all engaged in this field of work today but the principles are the same.

CHAPTER XII

Testing the Vitamin Content of Foods

THE MEASUREMENT OF VITAMIN B CONTENT

Sherman's method for determining the vitamin B value of foodstuffs is, like his A method, based primarily on growth curve evidence. White rats are the test animals. In his laboratory he has adopted as the unit of measurement the quantity of food which, as the sole source of vitamin B in an otherwise adequate diet, permits neither growth nor decline (i.e., just maintenance) in an eight-week period.

In applying the method in our own laboratory we have preferred to determine the amount which produces 20 grams gain in sixty days, as we find it a little easier to be sure of an amount which is producing a definite but small growth than one which is the exact maintenance requirement. With this minor difference in units, we have used his method with success and the details necessary to employ it follow:

Animals. White rats, thirty days of age, are

placed in separate cages with raised wire mesh bottoms.

Basal diet (Sherman No. 107)

	Per cent
Purified casein	18
Corn starch	68
Butter-fat	8
Cod-liver oil	2
Osborne and Mendel salts	4

Procedure. Place thirty-day-old rats from stock bred on diet No. 13 on the above basal diet and supply the food to be tested in weighed amounts daily, noting (*a*) weight gains every five days for sixty days; (*b*) intake of basal diet per rat per day; (*c*) evidences of complete protection from polyneuritis. Since rats do not store vitamin B, no preliminary regimen on a B-free diet is necessary. Since, however, rats void B in the feces the wire mesh screens at the bottom of the cages must be of such size as to let the feces fall through easily and thus be out of reach of the animals; otherwise they will eat the feces and modify the results of the test by so doing. The results of this test are shown in table 27.

Recently evidence has been accumulating to show that the vitamin B value of a foodstuff may be a summation of the effect of several fac-

tors. Using either rats or dogs, Goldberger and his co-workers showed that yeast heated in an autoclave retained its pellagra-preventive power but lost its antineuritic property. They also showed that an alcohol extract of white cornmeal would protect against polyneuritis but failed to

TABLE 27

Some results of testing methods from the author's laboratory

FOODSTUFF TESTED	AMOUNT NECESSARY TO INDUCE 20 GRAMS GAIN IN SIXTY DAYS UNIT	RELATIVE RICHNESS WHEN COMPARED WITH UNIT QUANTITIES OF MILK OR NATURAL TOMATO JUICE (6 CC. OF MILK OR 10 CC. OF TOMATO JUICE)
	grams	
Dried yeast	0.02	500 × tomato juice*
Raw peas	1–2	10–5 × tomato juice
Canned large peas	2	5 × tomato juice
Canned small peas	3	3 × tomato juice
Bananas (raw ripe)	8	1.25× tomato juice

* × = times.

give adequate protection against pellagra, whereas a suitable combination of autoclaved yeast and cornmeal extract produced normal growth and entire absence of both pellagric and polyneuritic symptoms. The cornmeal extract, however, was not entirely lacking in the P-P factor.

Autoclaving of yeast provides us with a test

substance containing the P-P factor and no antineuritic. We need also for testing a preparation containing the antineuritic in known quantity but lacking P-P. Such a preparation has apparently been developed by Peters and Kinnersley of Oxford, England, and another such preparation by an entirely different method has been obtained by R. R. Williams working in the author's laboratory. Such preparations should enable us to retest substances already assayed by the Sherman or similar method, and determine how much of what we have called their B content is P-P and how much is antineuritic factor. Using autoclaved yeast in the basal diet we can measure the minimum protective dose of foodstuff necessary to prevent polyneuritis and substituting for the yeast the Peters' or Williams' product in the basal diet, we can measure the minimum protective dose of foodstuff against pellagra. Such modifications are now in process of development. Eijkman first showed that birds might be used to test for the presence of the antineuritic substance. Subsequent observers found that the ordinary pigeon would serve for the same purpose and this bird has been much used. In our laboratory we employ this bird and use a method worked out by R. R. Williams, our associate.

Young birds (about 300 grams weight) are placed in a large cage and identified by means of leg bands. They are allowed to eat polished rice and water *ad libitum*. The food to be tested, if small in amount, is carefully weighed into suitable doses and these doses enclosed in gelatin capsules.

TABLE 28

Minimum daily ration which must be added to a diet of polished rice to prevent the onset of polyneuritis in a pigeon of 300 to 400 grams weight

FOODSTUFF	DOSE	PROTECTION
	grams	
Wheat germ	1.5	Complete
Dried yeast	0.35	Complete
Cow's milk	35.0*	Complete protection not obtained
Cheese	8.0*	Complete protection not obtained
Lentils	3.0	Complete
Barley (unhusked)	3.7	Complete
Barley (husked)	5.0	Complete

* More than.

The capsulated doses are fed to the birds by pushing through the mouth, and thus loss is prevented as well as insurance of ingestion of the full dosage. On the polished rice alone the birds succumb to polyneuritis rapidly, hence if the capsules contain antineuritic substance the onset of the

disease is delayed or completely prevented. By varying the amounts fed it is a simple matter to arrive at the minimum protective dose of any food under test, provided that food is rich enough in vitamin to be usable in this way. The British Medical Research Committee in 1919 (Special report No. 38) cited the results in table 28, obtained by this method.

This method in some form was largely employed by the earlier workers but aroused criticism because polished rice lacks so many other nutritional factors beside vitamin B. Simmonet and Randouin have suggested the following basal diet for pigeons to meet this criticism:

Basal diet after Randouin and Simmonet

	Per cent
Purified casein	7.5
Purified muscle residue	8.5
Osborne and Mendel salt mixture	4.0
Pulverized agar-agar	8.0
Butter-fat	4.0
Filter paper	2.0
Yellow dextrin	66.0
Total	100.0

N.B. Mix with 80 per cent of the weight of water and make into pellets. Twenty grams daily of this diet plus an adequate supply of antineuritic vitamin keeps pigeons normal. Pigeons on this diet alone develop polyneuritis in thirty days and die within four days hereafter unless protected. Five-tenths gram of dried yeast daily will fully protect them.

This variant of pigeon testing meets the criticism leveled at polished rice as a basal diet but tests in our laboratory have shown little advantage over polished rice for such pigeon tests.

A more important discovery has been that pigeons apparently do not, like rats, require the P-P factor but do need a third factor, not antineuritic. This result has emphasized the desirability of extending tests to more than one type of animal. Emmett has recently reported very successful use of young chicks for this purpose.

THE MEASUREMENT OF VITAMIN IN C VALUES

Deprivation of vitamin C does not produce scurvy in the rat. In fact, there is evidence that this animal can synthesize enough vitamin C to meet its body needs, for the livers of rats can be used to prevent scurvy in other animals. Monkeys may be used as test animals but their cost is high and they are very prone to infection. The plentiful and prolific guinea pig is highly suitable for this test and has come into almost universal employment for that purpose. In fact, some have criticized the drawing of conclusions in regard to antiscorbutic potency from the behavior of this animal, on the ground that it is so much more

susceptible than the human being to the disease as to perhaps mislead the testers.

In our laboratory the guinea pig is our exclusive test animal for this purpose. For basal diet we use the one developed by Sherman and LaMer. Earlier workers induced scurvy in their pigs by an *ad libitum* diet of hay and water. The Sherman-LaMer diet is an improvement over this mixture in that it is adequate is known factors.

Sherman-LaMer basal diet

	Per cent
Ground whole oats	59
Baked skim milk powder	30
Butter-fat	10
NaCl	1

Most of our experiments have been performed with this basal diet. As work has progressed it has seemed probable that this diet can be improved by a little more roughage which the guinea pig likes, and possibly by the addition of cod-liver oil to insure adequate supply of vitamin D. We are, therefore, at present experimenting with the following:

	Per cent
Rolled oats	50
Wheat bran	9
Baked skim milk (powdered) (cooked until free of all vitamin C)	30

	Per cent
Butter-fat	8
Cod-liver oil	2
NaCl	1

It also has been found advantageous to secure in advance from the dry milk dealers a supply of skim milk powder from cows on winter rations, as this precaution reduces the amount of heating necessary to assure absence of vitamin C in that article of diet.

On either of these diets a guinea pig will die of acute scurvy in about twenty-five to thirty days. Antiscorbutic foodstuff added to the basal diet halts the incidence of the disease or completely protects against it in proportion to the richness of the vitamin therein, and since a sick pig fails to grow normally the growth curves supplement the autopsy findings to a degree. The antiscorbutic food value, however, is reported best in terms of minimum protective dose, for since scurvy has a well-defined syndrome with adequate diagnostic signs, we are primarily interested in the amount of food necessary to prevent the development of these symptoms regardless of growth changes. The incidence of scurvy is readily detected in the guinea pig because the earliest hemorrhages appear to occur in the knee joints, where they produce a

sensitivity and lameness quickly apparent to the observer. Autopsy supplements these signs unmistakably and certain observers use a scale of symptom severity to measure the relative effect of food-

TABLE 29

Some results by this method from the author's laboratory

FOODSTUFF TESTED	MINIMUM PROTECTIVE DOSE FOR GUINEA PIG
Tomato juice	2.5–3 cc.
Apples (fresh picked)	10.0 grams
Apples (cold storage)	20.0–40.0 grams
Grape fruit	5.0 grams pulp
Bananas (raw ripe)	5.0 grams
Bananas (baked in skins)	5.0 grams
Bananas (baked without skins)	15.0 grams
Raw cabbage	1.0 gram
Boiled cabbage	20.0 grams
Canned cabbage	4.0 grams
Raw spinach	1.0 gram or less
Home cooked spinach	10.0 grams
Canned spinach	4.0 grams (less than)
Raw peas (average market)	2.0 grams
Home cooked peas	5.0 grams
Canned small peas	3.0 grams
Canned large peas	4.0 grams

stuffs. We prefer to make our unit of comparison the smallest dose necessary to completely eliminate all scorbutic symptoms, with sufficient variation in dosage to fix this amount within narrow limits.

To translate these guinea pig results into human values it is then merely necessary to know the protective dosage of one food for human and for guinea pig. Then all other guinea pig tests may be assumed to be relative. Thus if 15 cc. of orange juice protects a baby, and 1.5 cc. a guinea pig, the human requirement of orange juice would be ten times that of the pig. Hence, if 5 grams of banana protects a pig we can expect 50 grams to fully protect a baby.

A review of these results with the comments will explain the relative human potency of these products (see table 29). They also illustrate how maturity and method of cooking can vary the vitamin C value of the same foodstuff.

THE MEASUREMENT OF VITAMIN D VALUES

For this purpose we turn again to the white rat, preferably young ones, for they are in process of rapid growth and show best the failure or success in bone formation. We have here a choice of several basal diets of which two are given:

(A) Sherman and Pappenheimer's rachitic diet No. 84

	Per cent
Patent white flour	95.0
Ca lactate	2.9
NaCl	2.0
Iron citrate	0.1

(B) E. V. McCollum's rachitic diet No. 3133

	Per cent
Rolled oats	40
Gelatin	10
Wheat gluten	7
NaCl	1
KCl	1
$CaCO_3$	2
Dextrin	38.5
Butter-fat	0.5

That of McCollum has the advantage of containing all the necessary dietary factors except vitamin D and produces better growth in the animals. Diet No. 84 was developed by the investigators to show that rickets could be induced or prevented by proper proportions of phosphate, for if in diet No. 84 we substitute for 2.9 per cent calcium lactate 2.5 per cent and add 0.4 per cent of K_2HPO_4 no rickets results. We have preferred diet No. 84 because it is easy to make up, and by substituting for part of the flour the food to be tested we can arrive rapidly at the vitamin value of that article in terms of per cent in the diet necessary to protect. For example, by replacing 1, 2, 3, 4, and 5 per cent of the flour with whole milk powder we were unable to prevent rickets, but if we replaced 1 per cent of the flour with the same milk powder, irradiated for

sixty seconds with the ultra-violet lamp set at a distance of 1 foot from the powder, we obtained full protection. Such an experiment showed not only that irradiation of milk powder creates a supply of vitamin D therein, but how much of the diet must be composed of this irradiated food to be effective. Obviously such a method permits wide variation of experiments. The animals under this regime will show results within thirty days.

To demonstrate presence or absence of vitamin D in the food we have three standard tests. The inorganic phosphate content of a rat deprived of vitamin D suffers a marked reduction. Examination of such content then serves to indicate adequacy or inadequacy of protection. Primarily, however, we are testing the power of the animals to deposit calcium in the cartilages.

Hence, examination histologically of the rib junctions, or of the ends of the long bones, will provide evidence. We can also employ the x-ray for this purpose. The so-called "line test" is made as follows: The rat is chloroformed and the knee bones dissected out. After freeing most of the adhering tissue, the end of the bone is slit with a sharp knife to expose the structure. It is then

placed in acetone for from twenty-four to forty-eight hours to extract the fat. At the end of that time it is placed in a 3 per cent silver nitrate solution for thirty minutes, and then the cut surface is exposed for two minutes to the ultra-violet rays of a mercury vapor lamp. A photochemical change results and the calcium deposits appear as densely blackened areas, while cartilage in which calcium has failed to deposit appears as clear white area. The extent of these two regions constitutes the diagnosis.

If the extent of calcium utilization is desired in more detail, the femurs or the entire animals may be ashed and the calcium content, determined quantitatively, contrasted with that of animals on a controlled adequate diet. Some workers employ the determination of per cent of ash in the femurs as a check on the line test.

THE MEASUREMENT OF VITAMIN E VALUES

The measurement of this value thus far has not been worked out satisfactorily from the quantitative basis. Evans and Bishop, in developing evidence of the existence of this vitamin, used the procedure as shown at top of following page.

Basal diet

	Per cent
Casein	18
Cornstarch	54
Lard	15
Butter-fat	9
Salt mixture	4
Plus 0.4 to 0.6 gram of dried yeast daily	

On this diet they found that ultimately male rats became sterile and female rats failed to produce satisfactory litters. When the method is developed it will be obvious that an amount of foodstuff just sufficient when added to this diet to prevent sterility in males, or fertility and normal reproduction in females, will be a minimum protective dose of vitamin E. At present we know that wheat germ and lettuce possess this factor in abundance and that meat contains it but in much smaller quantity per unit of weight.

CHAPTER XIII

How Does Cooking Affect Vitamin Values?

The methods described in the preceding chapter enable us to compare the vitamin value of foodstuffs. If the vitamins were comparable to sugar and salt, or even to protein and fat, a single determination of a given foodstuff would suffice and we rapidly could prepare tables such as we have for the nutrients, in which the vitamin value of all common foods would be listed. Unfortunately, the vitamins are sensitive to a number of factors which markedly affect their physiological activity. Among such factors are those met in ordinary cooking processes, such as temperature, duration of heating, acidity or alkalinity changes, oxidation, etc. But more than this, the vitamin content of a given foodstuff is not always the same. So far as we know, no animal can manufacture vitamins A, B or E, and, with the possible exception of the rat, vitamin C. The quantity of these vitamins in animal foods such as milk, butter, cheese, eggs, animal fats, etc., de-

pends upon the amount of these factors in the food which the producing animals ate. Milk, for example, can be made rich or poor in vitamin content by changing the diet of the cow.

Even the vitamin content of plant foods is variable. Maturity is a factor and we have found young peas much richer in vitamin C and poorer in vitamin B than the larger more mature seeds. In fact, it is possible to obtain vitamin C from dried mature seeds (in which the amount is very small) by sprouting these seeds, the sprouts manufacturing the vitamin.

All of these factors make for difficulty in the practical assay of vitamin values and have necessitated the development of experiments to determine the extent to which vitamin content is affected by each of the determinants, singly and in combination, a matter that consumes much time and is far from complete today. For this reason we are only beginning to formulate tables that show the amount of vitamin in raw foodstuffs and in the same foods under different methods of table preparation. Before discussing the effect of cooking as a whole then, let us review some of the studies that have cast light on this subject.

FACTORS WHICH AFFECT THE ACTIVITY OF VITAMIN C

Let us begin the review with the vitamin which is admittedly the most sensitive of all those defined to date, namely vitamin C, the antiscorbutic factor.

Milk is not a rich source of this vitamin under the most favorable conditions of production, a pint being the requirement for the protection of a child according to Hess. It was early shown that pasteurization of milk might so reduce this supply as to make it practically non-protective. Today, however, we know that by carrying out the pasteurization process in vacuo, and avoiding traces of copper in the pasteurizing vats, we can accomplish sterilization with practically no loss of the vitamin.

A few years ago Delf, in England, showed that whereas 1 gram of raw cabbage daily would protect a guinea pig from scurvy it took twenty times that amount if the cabbage had been boiled for one hour in an open kettle. Yet, 4 grams of canned cabbage daily was shown by the author to be perfectly protective. This canned cabbage had been heated just as long as the boiled cabbage

and at higher temperature but the heating was done after the cabbage had been sealed in an air-tight can. Various investigators have shown that canned tomato juice is practically as potent in vitamin C as raw tomato juice and yet practically all canned tomatoes have been heated for forty-five minutes in the can. On the other hand, if lemon juice is first neutralized and then allowed to stand in a room exposed to the air, but without heating, it loses in twenty-four hours practically all its antiscorbutic potency.

These observations, which have been abundantly confirmed, illustrate the danger of dogmatism in condemning or applauding a given treatment of foodstuffs as being destructive or protective of vitamin C, and the need of careful study of how each factor (temperature, reaction, duration of heating, exclusion of air) acts.

Fortunately, part of this story is now available through quantitative work of several investigators. In 1922 LaMer, Sherman, and Campbell reported a series of observations covering the effect of heating tomato juice in stoppered glass flasks at various temperatures and for varying periods of time. In reporting this series they used the following formula to obtain the per cent destroyed, as shown at top of following page.

$$\frac{\left\{\begin{array}{l}\text{Minimum amount of} \\ \text{heated food neces-} \\ \text{sary for protection}\end{array}\right\} - \left\{\begin{array}{l}\text{Minimum amount un-} \\ \text{heated food neces-} \\ \text{sary for protection}\end{array}\right\}}{\text{Minimum amount heated food necessary for protection}} \times 100 = \left\{\begin{array}{l}\text{Per cent vita-} \\ \text{min destroyed}\end{array}\right.$$

As applied to cabbage this fraction would be as follows:

	Grams
Amount per day per guinea pig necessary to protection (raw)	1
Amount per day per guinea pig necessary to protection (boiled on stove)	20

$\frac{20 - 1}{20} \times 100 = 95$ per cent destruction of vitamin C by boiling

Using the same method we would have the effect of canning as producing $\frac{4-1}{4} \times 100 = 75$ per cent.

With this system of report LaMer and Sherman state that tomato juice of natural acidity (pH 4.3) loses vitamin C value as follows on heating:

	Per cent destruction
Boiling one hour at 212°F	50
Boiling four hours at 212°F	68
Heating one hour at 140°F	25
Heating four hours at 140°F	35

These results show: First, the destruction was increased by raising the temperature. Second, it was increased by extending the heating period;

but, at either temperature it is interesting to note that the rate of destruction was much more rapid in the first hour than in the subsequent three hours, which would seem to indicate (since temperature was the same throughout) that some factor was operating in the first hour that was diminished in the later period and which could not be temperature.

At the time these results were reported, no explanation of what this factor could be was attempted. They did, however, at that time show that if the natural acidity was partially neutralized destruction was more rapid, indicating that acidity is a protective factor.

The great value of these studies lay in their quantitative nature, but popular interpretation of the results extended the deductions far beyond the statements of the investigators. Among such unwarranted statements was the announcement that heating any food one hour at 212° F. would destroy 95 per cent of its vitamin C; that canning processes must necessarily destroy all vitamin C was another unwarranted conclusion.

When we consider that we can and consume some 19,000,000 cases (24 cans to a case) of green peas annually in the United States, to say nothing of the

TABLE 30

Some results from the work of the author and E. F. Kohman in the study of the effect of commercial canning on the vitamin C content of foodstuffs

FOODSTUFF TESTED	METHOD OF TREATMENT	MINIMUM PROTECTIVE DOSE PER DAY PER GUINEA PIG
		grams
Cabbage...	Raw (unheated)	1
	Boiled in open kettle one hour at 212°F.	20
	Commercially canned-processed one hour at 248°F.	4
	Cooked twenty minutes in pressure cooker at 248°F.	20
	Cooked in fireless cooker until palatable	20–30
Peas......	Ungraded raw (no heating)	2
	Ungraded market variety cooked on stove for twelve to fifteen minutes at 212 °F.	5
	Commercially canned, small size-blanched in hot water five minutes; processed twenty-five minutes at 248°F.	3
	Commercially canned, average size (No. 3) blanched seven minutes; processed twenty-five minutes at 248°F.	3
	Commercially canned; large size (No. 6) blanched ten minutes; processed twenty-five minutes at 248°F.	4
	Commercially canned average like those above but before testing they were reheated as for the table by dumping into a saucepan and bringing to a temperature of 212°F.	3

TABLE 30—*continued*

FOODSTUFF TESTED	METHOD OF TREATMENT	MINIMUM PROTECTIVE DOSE PER DAY PER GUINEA PIG
		grams
Apples......	Raw and fresh picked from trees	10
	Raw but from cold storage	20+
	Commercially canned by ordinary process over	40
	Commercially canned but submerged in 2 per cent salt brine before putting into can	20

bulk of other canned articles it became important to determine carefully whether canning is as destructive as these experiments might seem to indicate.

Between the years 1924 and 1927 the author, with the coöperation of E. F. Kohman of the National Canners Association Laboratory, measured quantitatively the effect of the canning process in the preparation of apples, peas, spinach, peaches, corn, beets, strawberries, tomato pulp, and beans. Much of the data obtained has appeared in the scientific press. Many interesting results bearing on vitamin response to cooking developed from these studies. One result, however, was outstanding, namely, that while heating

does destroy vitamin C in foodstuffs the extent of the destruction can be much reduced by preventing access of air or oxygen to the food during the heating period. Table 30 gives some of the observed results. These results made it very clear that the canning process, in spite of higher temperatures and longer heating than in home cooking, frequently resulted in much less destruction of the vitamin. Why?

The hypothesis developed was that vitamin C is readily destroyed by combination with oxygen (oxidation) and that while this process is accelerated by raising temperature, or by continuity of heating as in the case of most chemical reactions, temperature and duration of heating are in themselves not the significant destructive agents. Such a hypothesis would explain why the heating after food is sealed in a can is less destructive than stove cooking, because in that event the air is very effectually excluded during the heating process. It also would explain why the peas that were heated after removing from the can did not suffer an apparent loss of vitamin C, for such peas would be unlike fresh ones, being practically oxygen-free when removed from the can. The removal of atmospheric oxygen, however, is not the only oxidative

agent, if the above hypothesis is true, for such removal in the canning of apples was not as effective as immersing the apples in brine before canning, which suggests that in this experiment the brine treatment removes some oxidative factor other than gaseous oxygen.

This hypothesis has been supported by other experiments. Previous to our work, Hess showed that minute amounts of copper (known to speed up oxidative reactions) will accentuate the effect of heating in vitamin destruction. We have found recently that the use of copper kettles in the preparation of tomato pulp produces more destruction of vitamin C than heating in tin-lined kettles, and such pulps can be shown to contain traces of copper. The storage of foods in an atmosphere of CO_2 or nitrogen gas, instead of air, has shown that under these conditions vitamin C destruction is reduced. Finally, the pasteurization of milk in vacuo without vitamin C destruction, referred to above, is another bit of evidence in support of the oxidative destruction hypothesis.

Recently (1927) LaMer, Kenny, and Sherman repeated the experiments reported above with this hypothesis in mind. By an ingenious device they were able to free tomato juice from all trace of

atmospheric oxygen and to keep it in this condition while being heated. The results confirmed in a striking manner the importance of the oxygen. The contrasts are given in table 31.

The results definitely show that removal of atmospheric oxygen reduces destruction. Such removal, however, which is probably much more efficient than any cooking device, does not com-

TABLE 31

Effect of heating tomato juice with and without removal of oxygen

TEMPERATURE	DURATION OF HEATING	PER CENT DESTRUCTION OF VITAMIN C IN JUICE	
		With oxygen removed	Without oxygen removed
°*F.*	*hours*	*per cent*	*per cent*
212	1	Not 10	50
212	4	20	68

pletely eliminate all destruction. If foods contain, as was suggested above, some other oxidizing agent than oxygen then that may be the explanation of this small destruction. On the other hand, there may be other factors involved in the application of heat that are destructive but not of an oxidative nature. Such factors if they exist must await further study.

Zilva has recently shown that the destruction

of vitamin C by oxidation is apparently an irreversible process, that is, he was unable to restore activity by the use of a wide range of reducing agents. With a concentrated product obtained from lemon juice and potent with guinea pigs in doses of 0.00045 gram daily he showed that if air was completely excluded this substance stood heating for a considerable period at 284°F. with no detectable reduction in potency. These experiments suggest that at present our hope of conserving vitamin C lies in preventing oxidation rather than in any hope of converting the oxidized vitamin back to its active state, though that method eventually may be shown possible.

These studies of the lability of vitamin C have been outlined at some length for they illustrate the futility of advice regarding cooking operations so far as they affect vitamin values until data is complete. We can summarize by stating that we know now a method of reducing vitamin destruction while heating a food, that in the presence of any oxidative influence the amount of vitamin C destruction will be increased by raising temperatures or extending the duration of heating, and that the use of soda or other alkalies and the consequent lowering of acidity will hasten vitamin

C destruction, other factors being equal. In connection with oxidation effects on vitamin C we should not omit from consideration a series of observations reported by Bezssonov. This investigator found that the act of pressing juice from raw potatoes in a hydraulic press destroyed the antiscorbutic potency of the vegetable. After the pressing neither the juice or the marc left in the press was active. The vitamin had totally disappeared.

Potatoes contain an oxidizing enzyme called laccase which is responsible for their turning black when exposed to air. Bezssonov suspected this enzyme of being responsible for the destruction of the vitamin. Through the studies of G. Bertrand, of the Pasteur Institute, it had been found possible to inactivate this oxidizing enzyme by use of a dilute acid. Bezssonov therefore mixed his raw potato slices (200 grams) with 5 grams of a mixture composed of 1 part citric acid and 4 parts sugar, before expressing the juice. The juice from this pressing did not turn black on standing, showing that the laccase was not functioning. Furthermore, this juice contained all the antiscorbutic vitamin present in the potato in active form. It may, therefore, be possible in certain cases to

protect the vitamin C value of foods by measures that instead of eliminating the oxygen remove the factors that permit it to act on the vitamin.

More care has been given to date to the study of the factors concerned with destruction of vitamin C than to those which affect other vitamins. Vitamins A, B, D and E have been found from the first much less labile than vitamin C. However, certain data bearing on their lability is becoming available and we may consider some of this data in what follows.

FACTORS WHICH AFFECT THE ACTIVITY OF VITAMIN A

Hopkins and Drummond have shown that the vitamin A content of butter can be reduced markedly by heating it while a current of air is bubbled through. This result suggests that vitamin A, like vitamin C, is susceptible to oxidation and that heat accelerates this process. It must, however, be borne in mind that vitamin A is distributed differently in animal products than in plant sources. It early was shown that the extraction of cotton seed with ether would remove the oil but leave the vitamin behind in the seed tissues, the oil being practically vitamin A free.

Ether extraction of milk on the other hand extracts both butter-fat and vitamin A. McCollum explained this difference some time ago by the following hypothesis. He suggested that in plants the vitamin is so bound that extractants like ether cannot liberate; that when animals eat the plants the process of digestion sets free the vitamin which then (being fat-soluble) goes into solution in the animal fat. Plant sources, then, would hold the factor in different linkage than it is found in animal fats.

This difference of binding suggested by McCollum finds support in some recent experiments of Quinn in Sherman's laboratory. Using the method of oxygen elimination employed so successfully in the vitamin C experiments, he studied the effect of heat on the destruction of vitamin A in tomato juice. Four hours' heating of such juice produced only 17 per cent destruction of the vitamin but this destruction was not appreciably increased by allowing oxygen free access. Quinn, therefore, concludes that oxygen is not a significant factor when a plant source of vitamin A, such as tomato juice, is heated. The Drummond-Hopkins results with butter-fat, however, have been abundantly confirmed. Quinn's results seem

to indicate that the vitamin in plant source is not only non-extractable by fat solvents but is less liable to injury by heat-oxygen combinations. If this is true we are confirmed in believing that ordinary cooking processes offer little danger to vitamin A in plant sources, but we must take some care to eliminate oxygen if we heat animal sources. A phase of our canning studies has seemed to confirm the view that plant sources are little reduced, if any, in vitamin A content, for two hours' heating of spinach at 248° F. failed to show any appreciable difference in its vitamin A potency when contrasted with either the raw product or the stove-cooked product.

FACTORS WHICH DETERMINE THE DESTRUCTION OF VITAMIN B

We have already seen that there are new views as to the complexity of vitamin B. If what we now call vitamin B consists of an antineuritic factor and a pellagra preventing factor it may well be that each will have different response to make to the destructive influences. To date when we speak of the destruction of vitamin B we have meant loss of antineuritic power, though in many cases growth curves have been the evidence adduced.

Using the Sherman method of testing with rats, Grose and Burton have studied the influence of oxidation and change in reaction in combination with heat so far as destruction of vitamin B is concerned. Burton's results are given in table 32. Oxidation affected the results very slightly if any.

TABLE 32

Effect of heat and change of acidity on the vitamin B content of tomato juice

TEMPERATURE	DURATION OF HEATING	DEGREE OF ACIDITY	DESTRUCTION	MEANING OF SYMBOLS
°*F.*	*hours*	*pH*	*per cent*	
212	1	5.2	10	Acid
212	1	7.9	30–40	Slightly alkaline
212	1	9.18	60–70	Alkaline
212	1	10.9	90–100	Strongly alkaline
212	4	5.2	25–35	Acid
212	4	7.9	65–75	Slightly alkaline

These results show that even at natural acidity there is a slow destruction of vitamin B by application of heat, but that as the acid is neutralized this destruction rapidly increases, and in a strongly alkaline medium may become complete in an hour. Such a result is sufficient evidence for us to avoid wherever possible the use of alkalies in cooking when

antineuritic vitamin B conservation is desired. The use of soda in the cooking of green vegetables is the only practice that occurs to mind as a possible menace of any serious importance in ordinary practice. Certainly most cooking processes suggest little danger to vitamin B, with this exception. Recent data indicate that the P-P factor is much less heat-labile than the antineuritic.

THE LABILITY OF VITAMINS D AND E

Quantitative data are meager. Qualitative experiments, however, seem to indicate that these vitamins are remarkably stable and not apt to be affected by any ordinary cooking process so far known.

PRACTICAL CONSEQUENCES OF THE FOREGOING

It is impossible to discuss the problem of cooking and vitamins without a knowledge of the type of experimentation and evidence on which advice rests. For that reason it has been necessary to outline in detail a somewhat technical review of existing data. There is one point to be borne in mind by the layman. From the scientist's viewpoint the statement of vitamin destruction in percentages is necessary in order to permit com-

parisons in quantitative terms. It may, however, lead to false impressions. Take tomato juice, for example. Boiled in a flask it undergoes 68 per cent vitamin C destruction under certain conditions. Does this mean that boiling tomato juice will render it of no value as an antiscorbutic? Apply the equation by which this percentage was obtained, with the knowledge that 3 cc. of unheated juice will protect a guinea pig:

$$\frac{x-3}{x} \times 100 = 68 \text{ per cent, solve for } x \text{ and we get } x = 9.3 \text{ cc.}$$

In other words, 68 per cent destruction means that we must use 9.3 cc. of boiled juice to get the effect of 3 cc. of unboiled juice or about three times the amount. Now if the human requirement were only five times that of the guinea pig we still could use boiled juice as an antiscorbutic if we used 45 cc. instead of 15 cc., about $1\frac{1}{2}$ ounces. This is not a very large quantity in fluid measure or in weight.

The point that it is desired to make is that to appreciate the practical significance of the cooking process as applied to vitamin value we need to know at least four things:

1. What is the minimum human protective dose of the foodstuff.

2. What is the per cent destruction by cooking.

3. What is the size of the dose required after cooking to protect human beings.

4. Is this dosage more than the human would ordinarily eat of the food.

A consideration of these four factors readily shows that even if cooking is highly destructive, but not complete, the richness of the food in the factors may still allow us to cook it, accept the high destruction, but by our consumption of the food in sufficient quantity completely eliminate any need for consideration of destruction from the practical viewpoint. Considered from this viewpoint the danger of loss of vitamins by cooking is found to be much less of importance than the selection of vitamin-rich foodstuffs.

CHAPTER XIV

How Do Vitamins Function in the Body?

The definition of a vitamin, given in a preceding chapter, explains that their omission from the diet results in certain specific disease effects which are readily recognizable. The definition, however, does not tell how the vitamins accomplish protection from such effects. Can this question be answered?

At present we must admit only very partial knowledge. Coöperative effort by chemists, physiologists, physicists and pharmacologists, all necessary to the solution of the problem, is pushing us toward the goal and it is perhaps worth while to review some of their contributions.

VITAMIN A

McCollum cites Livingstone, the explorer (1857) as the first to record the appearance of an eye disease which is now recognized as due to lack of vitamin A. In 1904 Mori described 1400 cases of what he called xerophthalmia or "dry eye disease" in Japanese children between the ages of

two and five years, and relief of these cases by dosage with cod-liver oil (the richest known source of vitamin A).[1] Bloch, in Denmark (1917), described similar cases in that country which he attributed to substitution of oleomargarine for butter in the diet.

In discussing the reports of Mori and Bloch, McCollum says:

> We (1917) correlated observations on rats with those reported by Bloch and Mori and came to the conclusion that xerophthalmia or keratomalacia produced experimentally in animals is the analogue of the condition which these authors have reported in man. On this evidence we formulated the view that this type of xerophthalmia is a manifestation of deficiency disease due specifically to lack of vitamin A.

Later hemeralopia, or inability to see by subdued light (night blindness), was also shown to be related to vitamin A deficiency. Several students have tried to unravel the relations between vitamin A deficiency and these specific diseases and to show just where the vitamin functions. The most

[1] Drummond has recently reported studies of sheep liver fat which seem to indicate that this substance may be even richer in vitamin A than cod-liver oil.

exhaustive of these studies are those of Mori (1922–1923).

Mori reported that the primary effect is drying of the lachrymal gland and failing to produce tears. In the absence of tears the conjunctival sac is not washed, bacterial growth multiplies, white corpuscles invade and their dissolution produces a sticky exudate that glues the lids together. The dryness permits a hardening or cornification of the outer coating of the eye, the cells flattening and piling up in horny layers. Ulcers then form on the cornea and in advanced stages this may perforate the cornea and the lens be extruded.

Mori also found the salivary glands affected, secretion of saliva being markedly reduced or at a standstill in all or some of the three glands, and abscesses often appear at the base of the tongue even before the eye diseases develop in animals deprived of vitamin A. Liver, pancreas, bowel, kidney and thyroid were apparently unaffected by lack of vitamin. The reproductive glands, however, lost power to function. The lungs seemed particularly liable to infection in absence of this factor and, in older animals, lung infections often occur before xerophthalmia. These observations certainly suggest that vitamin A functions

in controlling the activity of certain specific glands, for if the diseased condition is not too far advanced restoration of the vitamin in the diet produces almost miraculous cures. They also suggest that in some way vitamin A provides an agent for resisting infection. Osborne and Mendel noted that in vitamin A-starved rats, stones of calcium phosphate often appeared in the bladders. Calcium phosphate will precipitate in an alkaline medium. By lowering the resistance to bacteria these produce ammonia which makes the urine alkaline instead of as usual, faintly acid, and the stone formation then becomes the direct result of failure to resist the bacteria.

The relation of vitamin A has been studied extensively by Sherman and co-workers to determine how it may affect nutrition. That work led Sherman to state:

> While vitamin A may not hold the direct controlling relation to any one disease that vitamin B does to beriberi or vitamin C to scurvy, yet it is probable that of the three, vitamin A is the factor of greatest practical importance to nutrition and health, because so many of our staple foods are poor in vitamin A and because a dietary poor in this vitamin causes such widespread weakening of the body and increases its susceptibility to so many infectious diseases.

He calls attention to the fact that, in addition to the tracts noted by Mori, air passages, lungs, bladder, skin, sinuses, and the ear in particular, and appetite and digestion in general are all apt to suffer when the diet lacks vitamin A.

By contrasting two series of animals whose diet differed in amount of vitamin A and observing them up to time of natural death Sherman and MacLeod reported:

> The smaller amount of A proved sufficient for normal growth up to nearly adult size but not for successful reproduction and rarely did it support satisfactory longevity.

Since this vitamin is capable of storage, immediate lack in the diet may not appear, for during this time the body may be consuming its reserves. However, we cannot measure accurately how long a period of dietary deficiency can be continued with safety and common sense suggests avoidance of any deficiency by adequate daily intake.

The relation to infection has originated some interesting experiments now in progress in various parts of the country. These experiments have been made to determine whether daily dosage of cod-liver oil will reduce tendency to colds in

school children and, hence, increased school attendance. Such measures may prove of distinct value in conserving health, but it is more important that our selection of palatable foodstuffs shall supply this vitamin in amounts sufficiently large as to make such dosage unnecessary. This also seems perfectly feasible when we note the widespread distribution of this vitamin in nature. Butter, eggs, the green vegetables such as lettuce, spinach, and green peas, and certain root vegetables such as carrots and sweet potatoes, have it in abundance, while it is also present in fruits in generous amounts.

VITAMIN B (ANTINEURITIC FACTOR)

The relation of vitamin B to disease was first established by proving that this disease is of dietary origin. A classic pioneer experiment was performed by Fraser and Stanton, through the study of Javanese coolies on a diet made up almost exclusively of polished rice. Their work was soon confirmed elsewhere. Strong and Crowell working with volunteers in a Philippine prison divided them into three groups, each receiving a certain amount of fish, lard, bananas, potatoes, and sugar combined with rice in various forms. Funk re-

ports the results shown in table 33. Braddon studied cases of diets and beri-beri in the Mediterranean war zone and worked out an expression which should show the relation of vitamin content of diet to incidence of disease. First the foods used were divided into two groups, those containing vitamin and those deficient. To the foods composing the former vitamin values were given

TABLE 33

Relation of vitamin B to disease

GROUP NUMBER	NUMBER OF VOLUNTEERS	FORM OF RICE FED	NUMBER OF CASES BERI-BERI
I	8	White rice plus polishings	2
II	17	White rice alone	13
III	7	Unpolished rice	1 (mild case)

which suggested relative richness. The unit of comparison was wheat germ as 100. These foods were then mixed to form four different diets, two of which protected from beri-beri and two did not. The results are tabulated in table 34.

Of course we can quarrel today with some of the assigned values in this table but it was an interesting practical demonstration at the time that when the vitamin containing foods constituted less than five-tenths of the total diet beri-beri resulted.

Beri-beri was definitely indicated as a vitamin B deficiency disease, and its symptoms and prog-

TABLE 34

Comparison of four different diets

FOODSTUFFS	VITAMIN VALUE	BERI-BERI PRODUCING		SATISFACTORY DIETS	
		I	II	III	IV
Rice	0	800*	—	600*	800*
White bread	0	6,400	6,400	3,200	4,800
Jam	0	—	—	200	200
Sugar	0	400	400	200	—
Cheese	0	400	400	400	—
Dried fruit	0	—	—	400	—
Salt fish	0	—	—	575	—
Margarine, butter or oil	0	400	400	200	100
Let X equal total food containing little or no vitamin		8,400	7,600	5,750	5,875
Oatmeal	10	—	—	400	400
Fresh meat	10	1,200	1,200	850	1,200
Peas, beans or lentils	50	—	800	400	600
Potatoes or fresh vegetables	5	400	400	1,200	800
Let V equal total food containing vitamin B		1,600	2,400	2,850	3,000
Ratios of V/X in these diets		0.2	0.3	0.5	0.5

* Represents weekly consumption.

ress became a means of observing the specific effects of omitting vitamin B from diet. Un-

fortunately, beri-beri is much too complicated a pathological picture to permit ready separation of primary from secondary effects. Furthermore, when vitamin B is lacking in the natural diets other food factors are usually lacking, which makes the cases as they come to the hospital complicated syndromes of many causative factors. The study of such cases has thrown little clear light on what vitamin B actually does in the body, regardless of how much it has helped us to prevent beri-beri.

McCarrison tried to unravel some of these sequences and divided the effects of vitamin B omission into four groups:

I. There results a chronic undernutrition.
II. There is a derangement of the functions of digestion and assimilation.
III. The endocrine glands, notably the adrenals, fail to function normally.
IV. There is a definite malnutrition of the nerve tissue cells.

Each of these effects obviously produces secondary results or is perhaps itself a secondary result. McCarrison believed the primary necessity for vitamin B lay in the fact that it is a food (nucleo-past) for the cell nuclei. He states: "The whole morbid process is believed to be the result of nuclear starvation of all tissue cells." Findlay

and Cooper produced support of this view by making histological studies of the cell nuclei of vitamin B-starved animals, and demonstration of a nuclear degeneration that could be reversed by yeast feeding.

It is generally believed today that this explanation is inadequate. Uhlman has suggested that vitamin B is a drug in effect similar to pilocarpine, and Voegtlin at one time believed it to be like the hormone secretin which stimulates the flow of the digestive juices of the pancreas. Both of these views were effectively contradicted by the work of Mendel and Cowgill.

In Cowgill's work with dogs deprived of vitamin B there developed a spasm effect which disappeared when the animal was anesthetized with ether. Such an effect suggested that deficiency of vitamin B results in the presence of a toxic substance in the tissues. The origin of such a substance has had several explanations. Dutcher first noted that the catalase (an oxidizing enzyme) of the tissues decreased on vitamin starvation. He explained this by suggesting that the vitamin functions by inducing oxidation, and when absent the partially oxidized products accumulate as toxic matter in the tissues. Abderhalden and his

co-workers have also suggested its relation to tissue respiration. Drummond and Marian have recently reviewed this matter and measured the effect of vitamin B deprivation on oxidizing enzymes and the oxygen uptake of normal and beriberi muscles. Their results fail to demonstrate any difference in the two tissues except just before death and this terminal difference they attribute to starvation rather than to absence of a chemical principle supplied by the vitamin.

There yet remains active dispute as to whether vitamin B is concerned with carbohydrate metabolism. The affirmative view that it is necessary in order to burn carbohydrates was first advanced by Funk and later apparently disproved by Vedder. The controversy, however, refuses to stay settled. Randouin and Simmonet reported recently that by feeding pigeons a diet composed of proteins and fats with very little carbohydrate they could maintain normal weight and temperature for two or three months in entire absence of vitamin B. If carbohydrate was added to the diet disease developed rapidly in the absence of vitamin B. They also showed that the form of the carbohydrate used affected the quantity of vitamin B necessary. It is difficult to explain these results

and still hold that the utilization of carbohydrate is not affected by vitamin B. Still more recently Reader and Drummond have shown that when the diet is high in protein the utilization by the rat may be controlled by the ratio between the amount of protein and the antineuritic used. With yeast for example as a source of vitamin B they found good growth when the protein/yeast ratio was 5 or less but poor growth if the ratio exceeded 5. In the light of later work Drummond inclines to attribute this power of the yeast to its P-P content rather than to the antineuritic factor.

The difficulty of all hypothesis in the matter is that while omission of the vitamin from the diet can be shown to produce a given series of events, it is very difficult to say where this series started and what particular part the vitamin took in the sequence and the separation of vitamin B into at least two and perhaps more distinct factors has of course much complicated our problem, and perhaps accounts for the failure of previous workers to agree on certain observed effects.

It is evident that failure to know the exact place where the vitamin acts, though regrettable, does not prevent us from having a very definite picture of some of the things that will happen with its omission and how to avoid them.

Cowgill and other workers in Mendel's laboratory have repeatedly demonstrated that omission of the vitamin means loss of appetite and hence reduced food consumption. Of course, loss of appetite may be caused by other factors but such loss is a constant result of vitamin B deficiency. Cowgill has shown that the loss is not due to depression of the digestive secretions and his work in this connection disposed of Voegtlin's claim that the vitamin acted like a secretin. He did find, however, that the gastric muscles lose tone on omission of the vitamin and recover it with dosage of that factor.

This relation to appetite was demonstrated in another way, by the author, as early as 1917. In the New York Hospital the author, with Dr. Joseph Roper, treated some thirty cases of malnutrition in infants by giving with the usual milk formula a concentrated vitamin B solution. Most of the cases responded to this treatment favorably and the first sign of response was always the same, namely, stimulation of appetite and ability to eat and assimilate food that they had hitherto refused. It now is recognized that the addition of fruit and vegetable juices at an early age is desirable not only as a preventive of scurvy but

as a means of supplementing the vitamin B content of milk, a content never very high even in the best milk. This need of vitamin B complex has been recently emphasized by Sure.

Cowgill has also recently carried out some experiments that show a relation between vitamin B need and the weight and age of the animal. By the work with dogs and rats he was able to fix the amount of a vitamin concentrate just adequate to maintenance in the adults. Using this amount, he derived a formula and a vitamin constant which appears applicable to other adult rats and dogs and may be ultimately developed to express human needs. The formula is the following:

$$\underset{K_{\text{vitamin}}}{\text{The vitamin constant}} = \frac{\text{Vitamin per day}}{\text{Calories per day} \times (\text{weight})^{\frac{5}{3}}}$$

With the vitamin constant known for that particular animal in terms of a given source such as dried yeast we can convert the formula into the following expression and determine the vitamin per day requirement of any member of that animal family whose calorie requirement and weight are known, thus:

$$\text{Vitamin per day} = K_{\text{vitamin}} \times \text{calories per day} \times (\text{weight})$$

This formula appears to hold for adults but not for growing animals. Growth increases the need by an amount not yet reducible to formula.

The separation of what we have called vitamin B into multiple factors makes necessary an entirely new study of the mode of action of sources of vitamin B and until this study has reached further development comment is impossible. Goldberger has begun the study of foods as pellagra preventives and the human dosage thereof. He has already shown that 40 ounces per day of canned tomato juice will protect the human subject, thus determining both the content and human requirement data for this foodstuff.

VITAMIN C

Here again data are absolutely lacking as to exact method of functioning though the effects of omission are well known. The first of these effects appears to be a development of extensive hemorrhages, though susceptibility to scurvy varies greatly with the species of animal. In man, as in the guinea pig, hemorrhages about the knees and joints is quickly followed by bleeding of gums with ultimate loosening of teeth. In fact, it has been suggested that many so-called "country

rheumatisms" which clear up so quickly with shift to green diet in the spring are not rheumatisms at all but incipient scurvy.

Aside from the production of hemorrhages by omission, absence of the vitamin results in certain failure to properly utilize lime. The same proliferation of cartilage without lime deposition that occurs in rickets frequently follows vitamin C deficiency and *x*-ray pictures show that as subperiosteal scorbutic hemorrhages clear up, calcium deposition in the bones again becomes normal. Howe and Wolbach have outlined a hypothesis that C-deficiency prevents formation of intercellular materials.

In the field of infant feeding it has been realized that even milk that is fresh and from properly fed cows is often inadequate in this factor, and that safety lies in adding to the infant's daily milk feeding a good supply of vitamin C in the form of some concentrated food source. Orange juice was first suggested for this purpose and later tomato juice was found about equally effective. There is, however, no peculiar virtue in either of these sources as such, for any concentrated source of the vitamin that will be tolerated by the infant will do as well, and as our knowledge of vitamin

C distribution in foods is extended we shall have other ways of supplying this factor. However, since most fruits reinforce the supply of vitamins A and B the fruits will continue to occupy a valuable place as sources of this vitamin.

VITAMIN D

What we call vitamin D is a factor concerned principally in the control of the deposition of calcium in the cartilages, though whether this power is exercised in controlling the absorption of calcium from the gut into the blood, in regulating the calcium-phosphorus balance in the blood and tissue, or at the seat of lime deposition, none can today say.

As a measure of insurance against deficiency of this factor in the diet, it has become popular to recommend the use of cod-liver oil as an infant source in the same way as orange juice is given to protect against vitamin C deficiency. Cod-liver oil is a rich source of the factor and, unfortunately, outside of fish oils there is no known natural food that possesses it in such abundance, though egg-yolk contains a considerable amount.

As noted before, scientific discoveries of much importance have succeeded one another with

amazing speed in the study of this factor. The two of greatest importance were that our own bodies can create this factor in adequate amount if we expose the skin to the ultra-violet rays of the sun (skin of face and arms is enough if frequent enough), and that we can generate the factor in foodstuffs by bathing these foods in the same rays. At the same time we must realize that these rays will not penetrate window glass or layers of dust in the atmosphere which means exposure to the rays in the open air and not through a glassed-in porch. The effect of the rays on the body might suggest that they are themselves responsible for the bone formation were it not for the fact that cod-liver oil taken internally is effective, and that the rays create in foods something which when swallowed functions as well as cod-liver oil. Such studies strongly suggest that the rays create the chemical factor in the body or in the food and that when once formed it in some way controls the lime utilization.

At present we can say only, in regard to the function of vitamin D and its place of operation, that while we know it is concerned in the control of our use of lime, and while we also know that its omission from the diet of infants means rickets

and in adults porosity of bones, we must wait still longer for the investigators to tell us the whole story of lime and phosphorus, the factors concerned in their use and the rôle played by vitamin D in that drama.

VITAMIN E

We know today simply that both male and female generative organs require this factor in the diet to function normally, and that it is supplied by a wide range of substances which are ordinarily in the diet, hence its omission from diet is probably less likely than of any other of the vitamins described. It is the only one so far discovered that seems to be fairly abundant in flesh foods such as meat.

SUMMARY

It will be evident from this review that our knowledge of how or where any vitamin functions is extremely fragmentary and incomplete. In spite of this, however, the need of these factors in nutrition is imperatively indicated and while we would like to have a therapy of vitamins, know just how much of each to take, know when to increase our intake and how to measure doses, our

present knowledge at least enables us to select foods that contain them and, without resort to the druggist, to get enough from the market to prevent any disease developing through their lack.

The review also suggests the great need for progress toward isolation of the vitamins in pure form to permit analysis and study of method and site of action. While progress is being made we are still somewhat remote from the ultimate goal. It would be interesting to review this chemical research but to do so at present would contribute little to the immediate purpose of this book, which is, a presentation of the relation of nutritional factors. Table 35 shows, however, that steps toward vitamin isolation is making good progress.

TABLE 35*

VITAMIN	PREPARATION REPORTED BY	POTENCY OF THE CONCENTRATE IN GRAMS DOSAGE PER DAY NECESSARY TO PROTECT THE EXPERIMENTAL ANIMAL FROM DEFICIENCY DISEASE
A	Drummond	0.00001 gram daily for a 100 gram rat
B	Peters	0.00008 gram daily for a 300 gram pigeon
C	Zilva	0.00045 gram daily for a 300 gram guinea pig
D	Rosenheim and Webster	0.0001 gram daily for a 100 gram rat
E	Evans and Burr	0.0005 gram daily for a 200 gram rat

* After J. C. Drummond, *J. Roy. Soc. Arts.*, LXXIV, 369 (1926).

CHAPTER XV

How Shall We Select Our Vitamins?

It should be evident from what has preceded that the discovery of vitamins has made necessary the inclusion of these factors in the daily market basket. It also should be obvious that we lack the knowledge necessary for exact measurement of our requirement in any of these factors. What shall we do about it?

There is in the American public a well-developed taste for variety. No hotel, boarding house, or home can keep its patrons happy long on a monotonous diet. This craving for variety is not a substitute for intelligence in food choice, but it has been a very potent factor in reducing the degree of vitamin deficiency. Xerophthalmia, beri-beri, and scurvy are rare diseases in American hospitals. Rickets, unfortunately, is much too common, but lack of vitamin E probably never menaced any American family. Deficiency diseases in acute form are rare, which in itself indicates that our search for variety has protected us from serious lack of the more widely distributed vitamins, A, B, and C.

If this is true, it will follow that the danger of vitamin deficiency increases as variety is reduced. Such reduction occurs naturally in infancy where milk often forms the sole article of diet. It also may occur in certain geographical regions in certain seasons of the year, when for weather or other causes the supply of green vegetables and fruits is cut down. Regions such as Newfoundland and the Maine coast have developed occasional cases of beri-beri and scurvy due to an enforced régime of white flour and salt fish. And even in a market such as New York City, infantile scurvy, eye disease, and beri-beri may occur from poor milk.

Semi-famine conditions and infancy are those where attention to vitamin supply in diet becomes particularly imperative. The propaganda for including with the infant's bottle such adjuvants as orange juice, or tomato juice, or scraped vegetables, and cod-liver oil is worth heeding. For nursing babies it is important that the mother's milk be of rich vitamin content, and that can be attained only by seeing that the mother's diet is rich in natural sources of these vitamins. For bottle-fed babies, the same attention is necessary to both milk and cow feed.

Does semi-famine ever occur in places where good markets are available? McCollum says "yes" and cites the following meal as an example for criticism:

> The right kind of a diet can best be described by making clear that certain kinds of diets which we employ are unsatisfactory. If a man should go to a hotel dining room and order the following menu he would think that he had ordered a good dinner:
>
> | | | |
> |---|---|---|
> | | Clear soup | |
> | Broiled steak | | French fried potatoes |
> | Horse radish | | Buttered peas |
> | | Olives | |
> | Fried egg plant | | Butter |
> | | Hot rolls | |
> | Apple pie | | Coffee |
> | | Cheese | |
>
> If he was familiar with the science of nutrition he would know that this list of foods would not keep one in a healthy condition. It does not contain any of the protective foods, *milk and the leafy vegetables.*

Perhaps such criticism will be clearer if we list the deficiencies in a meat, bread, potato, sugar diet, shown in table 36. Few will deny that, even with our liking for variety, we as a nation make far too much of our diet from meat, white bread, white potatoes and white flour-sugar com-

binations. We may then take McCollum's advice literally, namely: "Each member of the fam-

TABLE 36

Deficiencies in a meat, bread, potato, and sugar diet

DESIRED NUTRITIONAL FACTORS	VALUE OF FOUR COMMON STAPLES IN THESE FACTORS			
	Meat	White bread	White potato	Sugar
Calories	Fair	Good	Good	Good
Protein	Good	Fair	None	None
Carbohydrate	None	Good	Good	Good
Fat	Fair	None	None	None
Protein quality	Good	Poor	—	—
Calcium	Poor	Poor	Fair	None
Phosphorus	Good	Good	Fair	None
Iron	Good	None	Poor	None
Vitamin A	Very little	None	Very little	None None
Vitamin B	Very little	None	Fair	None
Vitamin C	None	None	Very little	None
Vitamin D	None	None	None	None
Vitamin E	Fair	None	None	None

N.B.—The factors conspicuously missing are calcium and vitamins A, B, C, and D, all present in milk and leafy vegetables. Milk would also improve the protein quality of the mixture.

ily to take a quart of milk daily, two salads to be served and one leafy vegetable. The rest of the diet built up around these foods." Or, we may

deliberately assay the foods we like and then combine them in such proportions as to provide adequacy of all factors and if necessary include some

TABLE 37

Excerpt from government bulletin table

In this table the signs have the following meaning: + indicates that the food contains the vitamin, ++ indicates that the food is a good source of the vitamin, +++ indicates that the food is an excellent source of the vitamin, —indicates that the food contains no appreciable amount of the vitamin, ? indicates doubt as to presence or amount, * indicates that evidence is lacking or appears insufficient.

Group I. Fruits and vegetables

FRUITS	VITAMIN A	VITAMIN B	VITAMIN C
Apples raw fresh................	+	+	++
Apples raw dried................	*	*	— to +
Apples canned commercially......	*	*	++
Apples home cooked..............	*	*	+ to ++
Avocados (alligator pears)........	+	+++	*
etc., etc.			

less liked if the adequacy cannot be attained otherwise. In either case we see that appetite or mere variety cannot substitute for intelligent selection.

In various texts[1] on vitamins will be found

[1] Funk, C. The Vitamines. The Williams & Wilkins Co.
Sherman and Smith. Vitamins. Chem. Catalog Company.
Rose, Mary S. Feeding the Family. Macmillan.
McCollum.. Newer Knowledge of Nutrition. Macmillan.

tabulations in which vitamin values of common foods have been compared by a series of stars or plus signs. Such a table recently has been compiled by Sybil Smith for the Home Economics Bureau of the United States Department of Agriculture and is now available for distribution. It is the most up-to-date of any in the author's knowledge and the excerpt given in table 37 will make clear its plan. This bulletin has also a valuable bibliography citing the particular scientific studies on which the given values have been based.

It may be that to those to whom such data are unavailable the following list may be useful:

RICH SOURCES OF EACH VITAMIN

Vitamin A. Fish oils and fats, butter, egg yolk, milk, green vegetables and certain root vegetables such as carrots and sweet potatoes.[2]

Vitamin B. Whole cereals, dried seeds such as beans, peas and lentils, most root vegetables, green vegetables, fruits, nuts, milk and cheese to a lesser extent.

[2] For some unknown reason yellow color in foods is often but not infallibly an indication of richness in vitamin A. Thus yellow sweet corn contains more than does white, carrots than parsnips, and sweet potatoes than white.

Vitamin C. Fresh fruits and green vegetables. Canning process reduces the content of the raw fruit or vegetable somewhat but such foods are still good sources.

Vitamin D. Cod-liver oil, other fish oils, egg yolk, milk and green vegetables in much lesser degree.

Vitamin E. Whole cereals, meats, lettuce.

Foods liable to be lacking in vitamins: Meats (except vitamin E), fish, highly milled cereals such as white flour, white rice, degerminated corn meal, starches, gelatin, sugars, animal fats other than butter.

With such data available we can thoroughly endorse McCollum's advice:

> THE PLACE TO GET VITAMINS is in the market, in the grocery store, from the milk man, and from the garden and not from the drug store. The only exception to this is in regard to vitamin D, which is best secured from cod-liver oil.

Vitamins may, in time, become isolated or synthesized chemically. When that time comes we shall know more about exact requirements. It then may be possible to add to the drug store's stock such preparations and use them to meet deficiency but such need does not seem imperative today.

CHAPTER XVI

ARE THERE OTHER NUTRITIONAL FACTORS?

It has been suggested previously that mere inclusion in the diet of specific amounts of nutrients or vitamins will not necessarily mean adequacy of that factor for body operations. The utilization of a given weight of protein may be controlled and conditioned by the other components of the diet. The use of lime may be controlled by exposure to sunlight, by use of cod-liver oil, by eating oranges or milk-sugar, as well as by seeing that the intake is 1 gram per day.

There are many factors which we have not listed that are concerned in securing a normal nourishment for the body, and many of these factors we cannot and will not know until we know the definite fate of every foodstuff in the body, the factors which are concerned in its use or which interfere with its efficiency, and the manner and location of their action. In brief, our knowledge of nutrition is far from complete.

Are there any such factors whose function is now indicated? Let us consider the following

example. A man who knows that energy is derived from carbohydrate food proceeds to eat what seems to be the proper amount of starch and sugar. He obeys the known laws and supplements his starch and sugar with the proper protein, fat, mineral and vitamin factors. All goes well for a time, until one day his urine begins to show sugar, his blood becomes clogged with it and turns acid. Acute diabetes has arrived. What factor has failed to function?

Much has been learned about this disease in the past few years. Fundamentally, we know today that the pancreas gland which supplies certain of our digestive juices has another function. It produces a secretion that it pours directly into the blood instead of into the intestine. In this respect it is like the gland which we call the thyroid or the one over the kidney known as the adrenal, namely, glands of internal secretion. The secretion itself has been successfully extracted from animal pancreases by Banting of Toronto and purified for use in human beings. Abel has apparently isolated the active principle and we are on the road perhaps to its manufacture by laboratories. It is called insulin.

We know that what happened in our diabetic

was the failure of his own pancreas to provide this secretion. When the secretion failed the digestion of the starch went on as usual, but the tissues were unable to use the sugar thus poured into the blood. We know this because, thanks to Banting's work, we can now enable the diabetic to use this sugar by injecting the insulin into the body. But what does it do? Its use does not cure them for in no case yet reported has the injection of insulin restored the diabetic's own insulin production to normal. It simply enables them to use sugar so long as the injections are repeated. The answer is unknown. There are several explanations that have been advanced but they are all theories as yet. Furthermore, we are just as ignorant as ever as to how the diabetic's insulin was formed, how it operated and why the secretion ceased. Evidently, here is a nutritional factor of tremendous importance of which we have still to explain the relation to the use of food.

This is one example of the importance of the glands of internal secretion in controlling the nourishment of the body. It is interesting, because of recent developments of practical importance but it is not at all unique. There are other glands of similar method of activity equally im-

portant in the control of nourishment and equally obscure as to method. Besides these glands we know very little as yet of the control of the nerves that direct our involuntary muscles, the muscles of the stomach, intestine, etc. In the case of a contracted muscle it is still a mystery how the train of events that produces action, heat, fatigue and recovery are derived from the oxidation of the sugar in the muscles or how the oxygen is made to unite with this sugar. Hopkins, of Cambridge, England, has recently extracted a chemical substance that he calls glutathione, which is a sulfur complex and known to have a part in the operation.

So we could go on, and suggest a large number of problems whose solution is still incomplete and essential to complete knowledge of human nutrition. Their very suggestion answers the question that we asked at the beginning of this chapter, for there are many factors still to be described. Such description must await better knowledge of their method of activity and control.

Our text is concluded at this point with full knowledge that it is not a complete guide to nutrition. In fact, it is doubtful if such a guide is ever written. Recognition of the limitations

of human knowledge is sometimes quite as important as actual knowledge, for it makes us tolerant instead of dogmatic. It is very easy to say *do this* and *do that* or to obey such orders. It has been the author's intention in this book to present some of the vital facts that have been discovered, and at the same time so present them as to make clear that their use will not necessarily always result in the same reactions. We know enough about food selection today to suggest combinations that have worked well and others that have worked harm. We do not yet know enough to claim that these combinations are the *only* good ones or that they will function equally well with all individuals. The main object has been not to write a guide to correct eating, as one com piles a book on etiquette, but to try to express in simple language the progress and the problems in the field of nutritional science today. If its perusal will stimulate further reading and continuous interest in this problem among the public for which it is written, we may hope in the future to have better babies, better adults, fewer diseases and fewer faddists.

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